

ACTA RADIOLOGICA

FOUNDED IN 1921 BY OOSTA FORSHELL

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF DENMARK, FINLAND, NORWAY AND SWEDEN

EDITOR

ERIK LINDGREN

ASSOCIATE EDITORS

ULF RUDHE ULF BERGVALL

ADVISORY BOARD

Diagnostic radiology OLLIE OLSSON

Therapeutic radiology LARS GUNNAR LARSSON

Radiation physics KURT LINDBY

Radiation biology BERNHARD TRISUNJANT

EDITORIAL BOARD

Denmark G THORSEN S JAAK

Finland P VIRTAMA L R HOLSTI

Norway J FREDIAN DAKL E PUPPE

Sweden L G LARSSON G F SALTENAN

DIAGNOSIS

INDICES to Vol 15 (1974)

January March May July September November

Contents of Volume 15 — DIAGNOSIS 1

Water soluble contrast media and arachnoiditis—II—Reinvestigation of operated cases	
By L. IRTAN and M. ROSENCRANTZ	1
Post-operative pseudodiverticula (spurious meningoceles) of the cervical subarachnoid space	
By Y. W. KIM, JOHN DEBOER UNGER and P. J. GRINELL	16
Equi osseal opening of the blood brain barrier in the rabbit by different contrast media	
By S. I. RAPAPORT, H. H. THOMPSON and JEANNETTE M. BERNER	21
Observation on the cervical segment of the spinal canal by an extension device	
By Á. KOVÁCS	33
Phlebography in the Klippel Trenauay syndrome	
By M. LEA THOMAS and G. B. MACFIE	43
Scintigraphy as a screening test for carcinomas of the pancreas	
By K. WATANABE, K. KAWAHARA and K. MATSUURA	57
Radiologic diagnosis of ileal carcinoid tumours	
By E. BOJSEN, J. KAUDE and U. TYLEN	63
Organic tricuspid aortic insufficiency in children	
By J. T. MALLAMO and E. CARLSON	83
Film quality in mammary radiography	
By E. DEICHOEGERER, S. REICHMANN and M. BURR	93
High dose urography in advanced renal failure—II—Influence on renal and hepatic function	
By N. NINMAN and P. STAGE	104
Brain volume in acromegaly—An encephalographic investigation	
By C. RLOBERG	113
Cortical bone mass in acromegaly	
By D. G. JEROS, K. NALLIS, G. VELIVYIAS and P. KATHICHTIS	134
Moya moya vessels—collateral arteries of the basal ganglia—Malignant occlusion of the anterior cerebral arteries	
By K. ROSENBERG	145
Angiographic abnormalities in combined myositis ossificans and digital ischemia of the hand—Report of a case	
By A. M. DUNCAN	152
Pharmacovangiography of the left gastric artery in oesophageal anastomoses	
By A. LINDERGREN	157
Functional isotope phlebography of lower extremities	
By J. VITK, A. H. AX and F. M. RELL	161
Scintigraphy of the parasternal lymphatics in the rabbit using technetium 99m sulfide colloid	
By L. R. CORAYSON and K. JOHNSON	169

Grading of osteoporosis by skeletal roentgenology and bone scanning By N. DALEN and B. LAMKE	177
Instrument for isotope determination <i>in vivo</i> of mineral content of the jaw bone By N. BJÖRK, S. ELLIANDER, J. E. FALK and C. O. HENNINGSON	187
Angiography in gastric tumours By F. ELLÉN and N. FRICKERMAN	193
Aorta, heart and lung: effects in idiopathic pulmonary emphysema related to pulmonary function By B. NORDENSTRÖM and T. KOMAZAKI	198
Intravenous cholangiography and peroral contraceptives—A preliminary report By P. LINDGREN, G. F. SALTZMAN and E. ZELCHNER	17
Carcinoma of the gallbladder—A review of 158 cases By H. PETTERSSON	225
Arthrography of the knee with a modified technique By H. LARSEN	237
The tortuous basilar artery By M. HAVERLING	241
EEG, ECG and other recordings in cerebral angiography By K. TALLIS and A. LUNDQVIST	250
Abdominal dimensions and thickness of the subcutaneous fat in the fetus By U. EKARVIST and H. G. RINGLERTZ	257
Elimination of diazotized by peritoneal dialysis in renal failure By N. MELMAN and E. CHRISTENSEN	265
Increase of subcapsular renal pressure after intravenous sodium iodide and other parenteral contrast media—An experimental investigation By P. LINDGREN and G. F. SALTZMAN	275
Anal fistulography By S. ARSLAN, B. HOLMSTRÖM and B. ÖRSKOV	281
Percutaneous nephrostomy By J. E. ALMGREN and I. FERNSTRÖM	288
Efficiency of intensifying screens By S. RICHMAN	295
A mathematical model of narrow beam radiation methods By U. WILANDER	305
Radiologic examination of the small intestine by duodenal intubation By J. L. SELLNER	318
Instrument for the removal of a gastric bezoar By M. H. WHOLEY, E. A. ZIEGLER and M. MARSH	333
The vestibular aqueduct and the paravestibular canal—An anatomic and roentgenologic investigation By H. F. WILBRAND, H. RASK ANDERSEN and D. GELSTRUP	337
Lumbar myelography and adhesive arachnoiditis By L. IRTAN, R. SCOTTSON and B. SCOTTSON	356
Orbital phlebography—I—Technique By J. BRUNAR	369
Pedunculated tumours of the oesophagus—Two cases of lipoma By B. J. LILJEQUIST and A. WIKERÖ	383

Angiography in renal amyloidosis By L. ERELIUND and T. LINDBOLM	393
Three-dimensional selective angiography in the diagnosis of renal masses By V. HEDGECOCK	401
Angiography in collagenous disease of the kidney By L. ERELIUND and T. LINDBOLM	413
Lung aeration in the full-term newborn rabbit—Roentgenologic and histologic investigations By GERTIE GROESMANN, B. LAMKE and B. ROBERTSON	423
Inherited urinary haemorrhagic telangiectasia of the liver demonstrated angiographically By M. LEA THOMAS and HELEN CARTY	433
Soft tissue radiography of finger joints By S. REICHMANN, E. DECKHOFFER, K. G. STAUD, T. HEYMAN and T. STRAND	439
Homogeneity of intensifying screens By S. REICHMANN and C. G. HELANDER	449
Absorbed dose and integral doses to the patient and personnel from angiographic procedures By J. KADEFORS and G. SVANIN	454
Röntgen and the Nobel Prize—The discussion at the Royal Swedish Academy of Sciences in Stockholm in 1901 By T. KJELLBERG	463
Selective phlebography of the pancreas By J. GOTTLIN, A. LUNDBERGH and U. TYLÉN	474
Orbital phlebography—II—Anatomy of superior ophthalmic vein and its tributaries By J. BRIDGMAN	481
Computer assisted tomography of intracranial CSF circulation using a water soluble contrast medium By T. GRÖNTE and T. HEDENMARK	497
External factors affecting paraneural scintigraphy with technetium 99m sulphide colloid—An investigation in the rabbit By L. R. GORANSSON and K. JOHANSSON	508
Angiographic abnormalities following percutaneous needle biopsy of the kidney By R. KOHLER and J. ECKHART	515
Renal blood flow determined by angiography By L. LINGGREN and B. LUNDSTROM	529
The iliac compression syndrome By K. V. JOHANSSON, B. GOTTLIN and S. NORDSTRÖM	539
Sclerosing injection of esophageal varices through transhepatic selective catheterization of the gastric coronary vein—A preliminary report By A. LUNDBERGH and J. VANO	546
Chronic symmetric osteomyelitis—Report of a case By K. H. GUTTAERSON and H. I. WILBRAND	551
Dental root fracture diagnosed by polytomography By M. HÄGERLUND and G. RANSTROM	558
High voltage radiography By S. REICHMANN and C. G. HELANDER	561
Angle distortion in narrow beam rotation radiography By K. A. SAMFORS and U. WELANDER	570

Orbital phlebography—III—Topography of intraorbital sinus	577
By J. BRUNAR	
Angiographic features in congenital defects of the corpus callosum	595
By F. P. PROBST	
The cochlear aqueduct	612
By A. HANSEN-OLSEN and P. G. LINDGREN	
Hyperosmolality of the cerebrospinal fluid as a cause of adhesive arachnoiditis in lumbar myelography	619
By P. SLATE, E. AUTIO, J. SLOLAKEN and S. NORRBACK	
Differential diagnosis of space-occupying lesions in the kidneys with the scintillation camera	630
By S. NORDLÄNDER and P. E. ÅSÅD	
Parasternal scintigraphy with technetium 99m colloid in human subjects—A comparison between two techniques	639
By L. R. GORANSON and K. JONSSON	
Area distortion in narrow beam rotation radiography	650
By K. A. SAKTORIS and U. WELAENDER	
Combined thermography and isotope scanning in thyroid pathology	656
By G. GALLI, D. SALVO, L. TONCONI and G. DE ROMI	
Normal lymphographic variations of lumbar disc and inguinal lymph vessels	662
By A. HOLZSTEDT	
Röntgenographic signs and growth of early carcinomas of the colon rectum	670
By G. ESKELUND, C. LUNDSTRÖM and J. E. RÖNNQVIST	
Conceptual framework of a computer based library circulation system for the radiology file room	680
By J. WINTER and M. A. STEIN	
Books received	687

Subject index to Volume 15 — Diagnosis

ROENTGEN DIAGNOSIS

Nervous system

Water soluble contrast media and adhesive arachnoiditis—II	1
Post operative pseudodiverticula of cervical subarachnoid space	16
Equi osmolar opening of blood brain barrier by different contrast media	21
Cervical spinal canal observed by an extension device	33
Brain volume in acromegaly	113
Cortical bone mass in acromegaly	134
Major vessels—collaterals of basal ganglia	143
The tortuous basilar artery	241
EEG EOG and other recordings in cerebral angiography	250
Lumbar myelography and adhesive arachnoiditis	356
Orbital phlebography—I—Technique	369
Orbital phlebography—II—Superior ophthalmic vein	481
Orbital phlebography—III—Intraorbital veins	577
Angiographic features in congenital defects of corpus callosum	595
Hyperosmolality of CSF a cause of adhesive arachnoiditis	619

Digestive tract (incl biliary tract and spleen)

Scintigraphy as a screening test for carcinoma of the pancreas	57
Radiologic diagnosis of ileal carcinoid tumours	63
Pharmacangiography of the left gastric artery in oesophageal varices	137
Angiography in gastric tumours	191
Cholangiography and peroral contraceptives	217
Carcinoma of the gallbladder	225
Anal fistulography	281
Examination of the small intestine by duodenal intubation	346
Instrument for removal of gastric bezoar	333
Lipoma of oesophagus	383
Hereditary haemorrhagic telangiectasia of the liver	133
Phlebography of the pancreas	174
Sclerosing injection of oesophageal varices through transhepatic catheterization of gastric coronary vein	516
Signs and growth of early carcinomas of the colon rectum	60

Heart and Vessels (incl lymphatic vessels)

Phlebography in the Klippel Trenaunay syndrome	43
Radiologic diagnosis of ileal carcinoid tumours	65

Organic tricuspid valvular insufficiency in children	83
Moy-moya vessels—collaterals of basal ganglia	145
Angiographic abnormalities in myositis ossificans	152
Pharmacangiography of the left gastric artery in oesophageal varices	157
Functional isotope phlebography of lower extremities	161
Scintigraphy of the parasternal lymphatics in the rabbit using technetium 99m sulphide colloid	169
Angiography in gastric tumours	193
Aorta-heart and lung vessels in idiopathic pulmonary emphysema related to pulmonary function	198
The tortuous basilar artery	241
EEG-ECG and other recordings in cerebral angiography	250
Orbital phlebography—I—Technique	369
Angiography in renal amyloidosis	393
Three-dimensional selective angiography in diagnosis of renal masses	401
Angiography in collagenous disease of kidney	413
Hereditary haemorrhagic telangiectasia of the liver	433
Absorbed gonad and integral doses from angiographic procedures	434
Phlebography of the pancreas	474
Orbital phlebography—II—Superior ophthalmic vein	481
Factors affecting parasternal scintigraphy with ^{99m} Tc sulphide colloid	508
Angiographic abnormalities following needle biopsy of kidney	515
Renal blood flow determined by angiography	529
The iliac compression syndrome	539
Sclerosing injection of oesophageal varices through transhepatic catheterization of gastric coronary vein	546
Orbital phlebography—III—Intraorbital vein	577
Angiographic features in congenital defects of corpus callosum	593
Parasternal scintigraphy with ^{99m} Tc-colloid in human subjects	639
Variations of lumbar iliac and inguinal lymph vessels	662

Lungs, Pleura Mediastinum and Chest walls

Scintigraphy of the parasternal lymphatics in the rabbit	169
Aorta-heart and lung vessels in idiopathic pulmonary emphysema related to pulmonary function	198
Lung aeration in the full-term newborn rabbit	433

Bones and Joints (incl soft tissue)

Cervical spinal canal observed by an extension device	33
Cortical bone mass in acromegaly	134
Angiographic abnormalities in myositis ossificans	152
Grading of osteoporosis by skeletal roentgenology and bone scanning	177
Instrument for isotope determination of mineral content	187
Arthrography of the knee with a modified technique	237
Soft tissue radiography of finger joints	439

Chronic symmetric osteomyelitis	351
Dental root fracture diagnosed by polytomography	558

Ear Nose and Throat

The vestibular aqueduct and the paravestibular canal	337
The cochlear aqueduct	612
Combined thermography and isotope scanning thyroid pathology	656

Ophthalmology

Orbital phlebography—I—Technique	369
Orbital phlebography—II—Superior ophthalmic veins	481
Orbital phlebography—III—Intraorbital sinus	577

Uro Genital system

High-dose urography in advanced renal failure—II	104
Abdominal dimensions and thickness of the subcutaneous fat in the fetus	157
Elimination of diazurostat by dialysis in renal failure	765
Subcapsular renal pressure after intravenous sodium iodide and other contrast media	273
Percutaneous nephrostomy	288
Angiography in renal amyloidosis	593
Three-dimensional selective angiography in diagnosis of renal masses	401
Angiography in collagen disease of kidney	413
Angiographic abnormalities following needle biopsy of kidney	515
Renal blood flow determined by angiography	529
Space-occupying lesions in the kidneys diagnosed with the scintillation camera	650

ISOTOPES

Scintigraphy as a screening test for carcinoma of the pancreas	57
Functional isotope phlebography of lower extremities	161
Scintigraphy of the parasternal lymphatics in the rabbit using technetium $99m$ sulfide colloid	169
Grading of osteoporosis by skeletal roentgenology and bone scanning	177
Instrument for isotope determination of mineral content	187
Factors affecting parasternal scintigraphy with ^{99m}Te sulfide colloid	508
Space-occupying lesions in the kidneys diagnosed with the scintillation camera	630
Parasternal scintigraphy with ^{99m}Te colloid in human subjects	639
Combined thermography and isotope scanning in thyroid pathology	656

TECHNIQUE

Cervical spinal canal observed by an extension device	33
Film quality in mammary radiography	93

SUBJECT INDEX TO VOLUME 15 — DIAGNOSIS

ix

Instrument for isotope determination of mineral content	187
Anal fistulography	281
Percutaneous nephrostomy	288
Efficiency of intensifying screens	295
A mathematical model of narrow beam radiation methods	305
Instrument for removal of gastric bezoar	333
Homogeneity of intensifying screens	449
Absorbed gonad and integral doses from angiographic procedures	454
Computer assisted tomography of intracranial CSF circulation using water soluble contrast medium	497
Sclerosing injection of esophageal aneurysms through transhepatic catheterization of gastric coronary vein	546
High voltage radiography	561
Angle distortion in narrow beam rotation radiography	570
Area distortion in narrow beam rotation radiography	650
Combined thermography and isotope scanning in thyroid pathology	656

CONTRAST MEDIA

Water soluble contrast media and adhesion arachnoiditis—II	1
Equi-osmolar opening of blood brain barrier by different contrast media	1
Elimination of diazotate by dialysis in renal failure	263
Subcapsular renal pressure after intravenous sodium iodide and other contrast media	273
Lumbar myelography and adhesive arachnoiditis	336
Computer assisted tomography of intracranial CSF circulation using water soluble contrast medium	497
Hypertonicity of CSF—cause of adhesive arachnoiditis	619

MISCELLANEOUS

Röntgen and the Nobel Prize—The discussion at the Royal Swedish Academy of Sciences in Stockholm in 1901	463
Computer based library circulation system for radiology file room	680

List of Authors

- Ahlback S 281
 Almqvist L III 283
 Aard P F 630
 Auo E 619
 Badinger Jeannette M 21
 Bjork N 187
 Boyesen E 63
 Brumby J 369 481 577
 Burén M 93
 Carlsson E 83
 Carty Helen 433
 Christensen E 205
 Dalén N 177
 DeBoer Linger June 16
 Deutschgraber E 93 439
 De Ross G 656
 Duncan A M 152
 Edgren J 315
 Eben F 193
 Ekelund G 670
 Eklund L 393 413
 Elavson S 187
 Erasme U 257
 Falk J E 187
 Fernstrom I 288
 Fiecherman K 193
 Galli G 606
 Grönberg D 337
 Goranson L R 169 506 639
 Gotblin J 174
 Guthman B 339
 Grete T 497
 Grinnell III J 16
 Grossmann Gertrude 423
 Gustafson K II 51
 Härling M 241 508
 Hegedus V 401
 Helander C G 449 511
 Hemmingson A 119
 Hensson C III 187
 Heyman F 439
 Hindmarsh T 497
 Holmström B 281
 Huvar A 161
 Ikko D G 134
 Instam L I 336
 Johnson K A 339
 Jonsson K 169 506 639
 Katschus P 134
 Kaude J 65 431
 Kawahara K 57
 Kim Y W 16
 Knutson F 465
 Kohler R 315
 Kolbenstedt A 62
 Kovács A 33
 Kumazaki T 198
 Lamke B 177 423
 Lee Thomas M 43 433
 Levén H 237
 Lindequist B 383
 Lindgren P 217 273
 Lindgren F G 112
 Lindholm T 393 413
 Lindström C 670
 Ljungkrantz L 329
 Lunderquist A 157 474 546
 Lundervold A 230
 Lundström B 329
 MacBe C B 43
 Mallamo J T 83
 Manooch M 333
 Matsumura K 57
 Milman N 101 260
 Nordenström B 198
 Nordlander S 130
 Nordström S 39
 Norrbläck S 119
 Nyalles K 134
 Pettersson H 220
 Probst I P 39
 Rådberg C 113
 Ramström G 338
 Rapoport S I 21
 Rask Andersen H 337
 Reichmann III 93 110 130
 449 561
 Ringertz H G 237
 Rihlson B 423
 Rosencranz M I
 Rosengren J E 670
 Rosengren K 14
 Saltzman C F 217 273
 Säfström K V 570 650
 Sah D 606
 Selb K J I 318
 Sigstedt B 306
 Slatk P 619
 Stage P 104
 Stern M A 680
 Strand T 439
 Stord K C 439
 Sjöström R 304
 Suola S J 619
 Svab G 451
 Syk B 281
 Telle K 350
 Thompson H K 21
 Troccone L 150
 Tylen U 60 474
 Vang J II
 Valentini Ch 134
 Vitek J 161
 Vrabel I 161
 Wannabe K 57
 Welanders U 30 70 100
 Wholey M H 333
 Wberg A 383
 Wihstrand H F 337 511
 Winter J 180
 Zechner P 217
 Zikra I A 333

List of Supplements to Acta Radiologica

Nos 173-312

(Issued November 1974)

For Suppl. Nos 1-172 inclusive see list issued December 1960 in Vol. 54 fac. 6

The supplements are published from time to time and are not included in the subscription rate. Prices and year of publication of numbers already issued are detailed below.

- 173 ERIK ÖSTERLAD, BJÖRN WÄRTEN and SVEN ERIC E. ÖLLVIG. Disappearance measurements. Theoretical, technical, biological and medical aspects. 1959. *Price Sw. A 30*
- 174 LARS BILLING and ERIC SEVERIN. Slipping epiphyses of the hip. A roentgenological and clinical study based on a new roentgen technique. 1959. *Price Sw. A 3*
- 175 ÅKE HANVOLD. Studies on the distribution and fate of C¹⁴ and T labelled p-aminosalicylic acid (PAS) in the body. 1959. *Price Sw. A 25*
- 176 LARS BJÖRK. Cine-radiographic studies on the Fallopian tubes in rabbits. 1959. *Price Sw. A 25*
- 177 PERLA VLOOSCHUY. The roentgenographic slit methods. A survey and analysis of procedures based on the use of a narrow bundle of roentgen rays (scintigraphy). 1959. *Price Sw. Kr 11*
- 178 BENGT H. O. ROSENBERG. Determination of cell mass by direct X-ray absorption. 1959. *Price Sw. Kr 25*
- 179 S. HULTBERG, O. DANIEL, R. THORAEUS, H. J. VETTERLÖF and R. WALSTAM. Bilocum cobalt 60 therapy: the Radiumbometer. Equipment, technique and dose measurements. 1959. *Price Sw. A 35*
- 180 BENGT LILJ. Motor activity of the stomach. 1959. *Price Sw. Kr 25*
- 181 PER ANDERSSON. The diagnostic value of conventional radiological examination of the heart in adults. (Appendix by R. G. CARPENTER. An account of the statistical analysis of the relative heart volumes of 753 patients in various disease groups). 1959. *Price Sw. A 20*
- 182 H. M. TRUBY. Acoustico-cine-radiographic analysis considerations with especial reference to certain coarctational complexes. 1959. *Price Sw. A 35*
- 183 ERIK BJÖRK. Angiographic studies of the anatomy of single and multiple renal arteries. 1959. *Price Sw. A 30*
- 184 GUSTAF NOTTIL. A technique for destruction of the hypophysis using ¹⁹²Ir spheres. A radiologic, endocrine and histologic study. 1959. *Price Sw. F 35*
- 185 BENGT LILJEQVIST. The subarachnoid cisterns. An anatomic and roentgenologic study. 1959. *Price Sw. A 35*
- 186 BENGT LILJEQVIST. Pontine angle tumour. Encephalographic appearances. 1959. *Price Sw. Kr 30*
- 187 HOLGER SKOLDWORTH. On the design, physical properties and practical application of small condenser ionization chambers. 1959. *Price Sw. A 30*
- 188 JENS NIELSEN. *Acta et alia* GUST. L. Papers dedicated to Jens Nielsen, professor of radiotherapy at the University of Copenhagen, on his sixtieth anniversary, December 11. 1959. *Price Sw. A 10*

- 189 OLOF DAHL and KARL JOHAN VIKTERLOF Attainment and value of precision in deep radiotherapy. Some fundamentals with special reference to moving beam therapy with 200 to 250 kV roentgen rays and cobalt 60 gamma radiation 1960 *Pract. Sci. A* 35
- 190 RUNE SÖREMARK Distribution and kinetics of bromide ions in the mammalian body. Some experimental investigations using $\text{Br}^{82\text{m}}$ and Br^{a} 1960 *Pract. Sci. A* 30
- 191 ULF BORELL and INGVAR FERNSTRÖM Radiologic perimetry 1970 *Pract. Sci. A* 30
- 19 NILS LINDVALL Renal papillary necrosis. A roentgenographic study of 155 cases 1960 (Out of print)
- 193 PAUL EDINOLM The tomogram. Its formation and content 1960 *Pract. Sci. A* 30
- 194 RAIVO KIVILOTO Pleural calcification as a roentgenologic sign of non-occupational endemic asbestosis (Mineralogic appendix by OLAVI KUORO) 1960 *Pract. Sci. A* 25
- 195 SVEN SCHILLER Roentgenographic studies on epiphyseal growth and ossification in the knee 1960 *Pract. Sci. A* 35
- 196 K. A. HULTBORN and BO TÖRNERG Mammary carcinoma. The biologic character of mammary carcinoma studied in 517 cases by a new form of malignancy grading 1960 *Pract. Sci. A* 35
- 197 LARS R. HOLM The mitotic and radioprotective effect of cysteine and histidine in rat 1960 *Pract. Sci. A* 30
- 198 OSBORNE BARTLEY The isometric relaxation phase of the left ventricle. An electrokymographic study 1960 *Pract. Sci. A* 35
- 199 GUNNAR WILLER VESTBY Vaso-venous angiography in hypertrophy and carcinoma of the prostate with special reference to the ejaculatory ducts 1960 *Pract. Sci. A* 35
- 200 BJÖRN NORDENSTRÖM Contrast examination of the cardiovascular system during increased intrabronchial pressure 1960 *Pract. Sci. A* 30
- 201 GIOVANNI DI CINTIO RISA encephalography and conventional neuroradiologic methods. A comparative study 1961 *Pract. Sci. A* 35
- 202 LARS BJÖRK Vlopharyngeal function in connected speech. Studies using tomography and cinematography synchronized with speech spectrography 1961 *Pract. Sci. A* 25
- 203 BROR O. NYLÉN Cleft palate and speech. A surgical study including observations on lopharyngeal closure during connected speech using, synchronized cinematography and sound spectrography 1961 *Pract. Sci. A* 25
- *04 S. R. KJELLBERG, B. NORDENSTRÖM, U. RUDOLF, A. O. BJÖRK and G. MALMSTRÖM Cardioangiographic studies of the mitral and aortic valves 1961 *Pract. Sci. A* 30
- 205 C. L. CARLBERGER Kinetics and distribution of radioactive cobalt administered to the mammalian body 1961 *Pract. Sci. A* 30
- 206 HANS MÖLLER Kidney size and its deviation from normal in acute renal failure. A roentgenologic study 1961 *Pract. Sci. A* 25
- 207 LEIF KJELD HANSE Victrolite cystourethrography with automatic serial exposures. An opinion on the value of the method 1961 *Pract. Sci. A* 30
- *08 IIV LINDVALL Cancer of the vulva. A clinical review 1961 *Pract. Sci. A* 30
- 209 ILMAR LINDGREN Anatomical and roentgenologic studies of tuberculous infections in BCG-vaccinated and non-vaccinated subjects with biophysical investigations of calcified foci 1961 *Pract. Sci. A* 25
- 210 IIV TRIK F. BRONER The significance of certain tracer kinetic methods, especially with respect to the tracer dynamic definition of metabolic turnover 1962 *Pract. Sci. A* 30
- 11 IIV ORINEN, P. AHTILA, L. WEGELIUS, A. KALLILA and I. KOSKINEN Renal cortical index and other roentgenographic renal measurements 1961 *Pract. Sci. A* 25

- 212 LARS AXELSEN Pelvic instability in newborns with special reference to congenital dislocation of the hip and hormonal factors. A roentgenologic study. 1962 *Prac. Sc. A* 30
- 213 NILS-MAGNUS OHLSSON Left heart and aortic blood flow in the dog. Precision motion analysis of high speed (270 frames/sec) cinefluorographic recordings. 1962 *Prac. Sc. A* 30
- 214 BENGT TJERNBERG Lymphography. An animal study on the diagnosis of α x ? carcinoma and inflammation. 1962 *Prac. Sc. A* 35
- 215 PAAVO KLAMI Periarthrosis calcarea of the shoulder joint. Its differentiation from other stiff and painful shoulders. 1962 *Prac. Sc. A* 30
- 216 P. EDENLÖF, I. FERNSTRÖM, K. LINDGREN and S. I. SELDINGER Roentgen television in practice with special regard to puncture examinations. 1962 *Prac. Sc. A* 30
- 217 FOLKE EDENER Carcinoma of the vulva. An analysis of 560 patients with histologically verified squamous cell carcinoma. 1962 *Prac. Sc. A* 30
- 218 P. SOTLA, M. GROTHOOS, O. KAUPPILA and L. PYRÖNEN Wasserlösliche kontrastierbare wasserlösliche und jodolische Kontrastmittel in der Hysterosalpingographie. Vergleichende Untersuchungen. 1962 *Prac. Sc. A* 25
- 219 STEN SANDMARK Hiatal incompetence. Studies on mechanics and principles of examination for hiatus hernia and gastro-oesophageal reflux. 1963 *Prac. Sc. A* 20
- 220 MAX LUNDHOLM Free movements in the temporomandibular joint. A cineradiographic study. 1963 *Prac. Sc. A* 30
- 221 ÅKE NORRAGREN Selective angiography of the hepatic veins. Experimental investigations of basal circulatory dynamics. 1963 *Prac. Sc. A* 35
- 222 ERLING HANSEN JACOBSEN Genetically significant radiation doses in diagnostic radiology. 1963 *Prac. Sc. A* 30
- 223 ARVID BROHULT Allylthioglycerols and their use in radiation treatment. An experimental and clinical study. 1963 *Prac. Sc. A* 30
- 224 CARL OLOF ÖVERGREN Pulmonary interstitial emphysema—An experimental roentgen-diagnostic study. 1964 *Prac. Sc. A* 35
- 225 GEORGE THILANDER Variation in shape of gallbladder during cholecystography. 1964 *Prac. Sc. A* 30
- 226 HILLO BOGAREV The composition and structure of human gallstones. 1964 *Prac. Sc. A* 30
- 227 LARS NORDQVIST The sagittal diameter of the spinal cord and subarachnoid space in different age groups—A roentgenographic post mortem study. 1964 *Prac. Sc. A* 25
- 228 LÖNNVART VIKTORIN Bone resorption in cases with complete upper denture—A quantitative roentgenographic photogrammetric study. 1964 *Prac. Sc. A* 30
- 229 ARNIM FAGERSTEDT Irradiation of lymph nodes and enamel—Experiments in rats with reference to cancer therapy. 1964 *Prac. Sc. A* 30
- 230 LARS HOLLANDER Determining the elements of the minor orientation in roentgenography. 1964 *Prac. Sc. A* 30
- 231 HANS HENRIK HOLM The hydrodynamics of micturition—Examination by means of micro-manometer and uroflowmeter of the hydrodynamic conditions in normal subjects and in patients suffering from obstruction in the posterior part of the urethra. 1964 *Prac. Sc. A* 30
- 232 ERIK ÖDERGREN Clinical application of whole body counting of ^{45}S and ^{45}Ca in patients with and without widespread malignant skeletal disease. 1964 *Prac. Sc. A* 30
- 233 SVEN PAULIN Coronary angiography—A technical, anatomical and clinical study. 1964 *Prac. Sc. A* 40
- 234 TRÖLLI MÜLLER The influence of para-aminosalicylic acid on the I^{131} metabolism. 1965 *Prac. Sc. A* 30

- 235 A. DERI LÄNDERQVIST Angiography in carcinoma of the pancreas 1965 *Price Sw. Kr. 35*
- 236 RUNE WALSTAM Studies on therapeutic short distance and intracavitary gamma beam techniques—Physical considerations with special reference to radiation protection 1965 (Out of print)
- 237 KAI SETALA Differences in pharmacodynamic response to colchicine between benign and malignant epidermal hyperplasias—An experimental study in skin tumor resistant mice 1965 *Price Sw. Kr. 30*
- 238 ULO ERICSON Circulation in traumatic amputation stumps—An angiographical and physiological investigation 1965 *Price Sw. Kr. 35*
- 239 CARL GUSTAF SÄNDERTEGJÖLD NORDENSTAM The pulmonary circulation during pneumonia—A cineangiographic study 1965 *Price Sw. Kr. 35*
- 240 AVTTI CEDERBERG Granulocyte distribution in bone marrow blood and different organs in whole body irradiated rats 1965 *Price Sw. Kr. 35*
- 241 KAI SETALA Decorporation of radiostrontium Radiometric assay techniques—An experimental study on mice 1965 *Price Sw. Kr. 30*
- 242 SUTUJI TAKAHASHI Conformation radiotherapy—Rotation techniques as applied to radiography and radiotherapy of cancer 1965 *Price Sw. Kr. 40*
- 243 J. TH. VAN DER WERFF Radioactive bismuth ²¹²Bi—Experimental studies and clinical applications 1965 *Price Sw. Kr. 35*
- 244 SAMUEL S. KUROHARA Effects of ionizing radiation on creatine metabolism in patients treated for malignancy and in rats 1965 *Price Sw. Kr. 35*
- 245 PER WESTLUND Studies of the prognosis in Hodgkin's disease 1965 *Price Sw. Kr. 35*
- 246 SVEN GOTTMAR ERICSON Quantitative microradiography of cementum and abraded denture—A methodological and biological study 1965 *Price Sw. Kr. 35*
- 247 MAURIT WELJAMÄLÖ Lymphographic differential diagnosis of neoplastic diseases 1965 *Price Sw. Kr. 35*
- 248 STEN SCHILLER Roentgenographic studies on the ossification of the distal femoral epiphysis 1965 *Price Sw. Kr. 30*
- 249 ROAR NØRE MEYER Castration as part of the primary treatment for operable female breast cancer—A statistical evaluation of clinical results 1965 *Price Sw. Kr. 35*
- 250 ELS BEVERT SVEN HULTBERG HANS-LUDVIG KOTTMERER ROLF SIEVERT LARS S. TERNØY and BEGT SYLVA The first fifty years Radumbeinet 1910—1957 and Hans Gustaf V. J. Åberg Clin. 1938—1960 1965 *Price Sw. Kr. 30*
- 251 MATS HÄVERLUND Renal phlebography—An experimental study in the pig 1966 *Price Sw. Kr. 30*
- 252 GUNAR WESTER Gas myelography and percutaneous puncture in the diagnosis of spinal cord cysts 1966 *Price Sw. Kr. 30*
- 253 SVEN I. AR SELDINGER Percutaneous transhepatic cholangiography 1966 *Price Sw. Kr. 35*
- 254 FIRST NORDIC RADIATION PROTECTION CONFERENCE Proceedings Stockholm 1966 Edited by K. Lidén and Erik Lindgren *Price Sw. Kr. 35*
- 255 LAWRENCE JOSEPH A. CURA Application of digital computers in radiation dosimetry 1966 *Price Sw. Kr. 35*
- 256 H. A. LUDEN Aortography Fluid dynamics and technical problems 1966 *Price Sw. Kr. 35*
- 257 HJALMAR BOLIN Contrast medium in kidney during angiography—A densitometric method for estimation of renal function 1966 *Price Sw. Kr. 30*

- 238 ELISABETH JOHANSSON, PER HOLSTAD and GUNNAR SÖDERBERG. Cytologic, vascular and histologic patterns of dysplasia, carcinoma in situ and early invasive carcinomas of the cervix. 1966 *Prior Sc. A* 40
- 239 PAUL EDVOLL. Anatomic angles determined from two radiographic projections—Instrument description and measurement techniques. 1966 *Prior Sc. A* 40
- 260 TORSTEN ALVÉN. A steering device for selective angiography and some vascular and enzymatic reactions observed in its clinical application. 1966 *Prior Sc. A* 40
- 261 KAI SETÄLÄ, BJÖRN LINDROOS and OTTO NYTTERÖN. Cancer chemotherapy studies: cytoplasmic barrier in malignant epidermal cells against the effect of colchicine—An electron microscopic study in mice. 1966 *Prior Sc. A* 25
- 262 ALAS ROSENBERG. Hyaline membrane disease—A radiological investigation in rabbits. 1967 *Prior Sc. A* 35
- 263 JAN NILSSON. Angiography in tumours of the urinary bladder. 1967 *Prior Sc. A* 35
- 264 PER ERIK HENCKEL. Postmortal changes of the lung—A roentgenographic, microscopic and bacteriological follow up study on a pediatric series and on animals with experimental pneumonia. 1967 *Prior Sc. A* 30
- 265 KAI SETÄLÄ, OTTO NYTTERÖN and BJÖRN LINDROOS. Ultrastructural changes in benign and malignant epidermal states in mice after topical beta radiation. 1967 *Prior Sc. A* 30
- 266 GÖRAN NYLANDER. Vascular response to vasopressin as reflected in angiography—An experimental study in the dog. 1967 *Prior Sc. A* 35
- 267 JÖRAN FOLIN. Angiography in renal tumours—Its value in diagnosis and differential diagnosis as complement to conventional methods. 1967 *Prior Sc. A* 35
- 268 ERIC TALA. Carcinoma of the lung—A retrospective study with special reference to pre-diagnosis period and roentgenographic signs. 1967 *Prior Sc. A* 35
- 269 CARL O. HENRIKSSON. Iodine 125 as a radiation source for odontological roentgenology. 1967 *Prior Sc. A* 35
- 270 CATIONS IN INTRAVASCULAR CONTRAST MEDIA AND DEVELOPMENT OF SPECIFIC METRIZOATE FORMULAS—PHARMACOLOGIC AND CLINICAL STUDIES. Proc. Symposium at Copenhagen, November 1964 and Sandefjord, September 1966. 1967 *Prior Sc. A* 40
- 271 ERNA TARKIANGEN. Intracostal vein meningorachnoidography—A technical, anatomic and clinical study. 1967 *Prior Sc. A* 35
- 272 ALLAN LUNDENQVIST. Arterial segmental supply of the liver—An angiographic study. 1967 *Prior Sc. A* 35
- 273 KAI SETÄLÄ, MÅR STURALA, OTTO NYTTERÖN and ERNA TARKIANGEN. Quantitative three-dimensional scintillography of the stomach with technetium (^{99m}Tc). 1967 *Prior Sc. A* 30
- 274 PER BENGTSSON. Radiation induced early changes in size and vascularity of cervical carcinoma—A colposcopic and clinical study. 1968 *Prior Sc. A* 35
- 275 SVEN EKLUND. The parotid gland in subjects with and without rheumatoid arthritis. 1968 *Prior Sc. A* 40
- 276 ROLF JENSEN. Anterior teeth relationship and speech. Studies using cineradiography synchronized with speech recording. 1968 *Prior Sc. A* 35
- 277 SVEN ANDERSSON. Outgrowths of the knee—A radiographic investigation. 1968 *Prior Sc. A* 35
- 278 IRÉNE SJÖQVIST, KJELL BERGSTRÖM and HERMAN LÖNN. Echoencephalography in infants and children. Comparison with cerebral pneumography in measuring ventricular size. 1968 *Prior Sc. A* 35

- 279 BERTIL JARPLID Radiation induced asymmetry and lymphoma of thymus in mice 1968 *Price Sw. Kr* 35
- 280 EERIKI M. LAAMONEN Information transmission in roentgen diagnostic chains—Experimental and clinical studies 1968 *Price Sw. Kr* 35
- 281 RARULS SJENSTRÖM Arthrography of the knee joint in children—Roentgenologic anatomy, diagnosis and the use of multiple discriminant analysis 1968 *Price Sw. Kr* 35
- 282 KARL KARLSTEDT Carcinoma of the uterine corpus—Factors bearing on the curability 1968 *Price Sw. Kr* 35
- 283 LEO STJERNVALL Pharmacodynamic response of epidermal hyperplasias to topical vinblastine treatment 1968 *Price Sw. Kr* 35
- 284 HANS FLODIN Distribution and kinetics of labelled vitamin B₁₂ 1968 *Price Sw. Kr* 35
- 285 EERIKI KORHONEN Comparative study of roentgen diagnostic classifications—Computer analysis of 124 496 roentgen reports 1969 *Price Sw. Kr* 35
- 286 JORGEN JENSEN Malformations of the inner ear in deaf children—A tomographic and clinical study 1969 *Price Sw. Kr* 35
- 287 PENTTI J. TAKKINEN Radiotherapy and TNM classification of cancer of the larynx—a study based on 1 447 cases seen at the Radiotherapy Clinic of Helsinki during 1936–1961 1969 *Price Sw. Kr* 35
- 288 ROBERT T. NASH Decision processes employing radioisotope scanning 1969 *Price Sw. Kr* 35
- 289 STIGER WILJASALO Lymphographic polymorphism in Hodgkin disease—Correlation of lymphography to histology and duration 1969 *Price Sw. Kr* 35
- 290 LEO WELANDER Multicolor combination images in subtraction angiography—A new photographic method and its applications 1969 *Price Sw. Kr* 40
- 291 LENA SCHIRACK PUROLA Failure of malignant epidermal cells to respond to vinblastine sulfate—A study in skin tumor resistant mice 1969 *Price Sw. Kr* 35
- 292 GIOVANNI RUGGERO GIANFRANCO CRISTF and CLAUDIO TREBBIANI Clinical aspects of encephalography 1969 *Price Sw. Kr* 30
- 293 PERKA VIRTAMA and TAMMO HELELA Radiographic measurements of cortical bone—Variations in a normal population between 1 and 90 years of age 1969 *Price Sw. Kr* 30
- 294 LEO STJERNVALL E. E. NISKANEN and J. TARAKANEN Penetration of cytoplasmic barrier in malignant epidermal hyperplasia by colchicine in dimethyl sulfoxide—A polarization microscopic study in skin tumor resistant mice 1969 *Price Sw. Kr* 20
- 295 KAARINA TOIKARI KASILA Heart size determination by photofluorography 1970 *Price Sw. Kr* 35
- 296 HANS ROYVING Otosclerosis—A tomographic-clinical study 1970 *Price Sw. Kr* 35
- 297 ILE LANGELAND Population screening for female breast tumours—A clinical investigation 1970 *Price Sw. Kr* 35
- 298 JOHAN FJORE Effect of cysteine on chromosome aberrations induced by radiation of human lymphocytes in vitro 1970 *Price Sw. Kr* 30
- 299 RENE SANDREN Selectin angiography of the left gastric artery 1970 *Price Sw. Kr* 35
- 300 NIELS KRONHARDT The lower urinary tract in infancy and childhood—Micturition urography with simultaneous pressure flow measurement 1970 *Price Sw. Kr* 35
- 301 M. VIKKARI Ultrasound examination of pleural plaques—Experimental pathologic and clinical studies 1970 *Price Sw. Kr* 35
- 302 INGEMAR JOELSON Radiotherapy of carcinoma of the uterine cervix with special regard to external irradiation 1970 *Price Sw. Kr* 35

- 303 KAARINA AANTAA Location of the placenta—A comparison between radiography, ultrasound, thermography, isotopes 1971 *Price Supp. A* 25
- 304 LEMMART DIETTER I. transosseous phlebography of the lower limb—Postmortem investigation of thrombotic venous disease 1971 *Price Supp. A* 40
- 305 ERICND STROMBERG The normal and diseased superficial flexor tendon in race horses—A morphologic and physiologic investigation 1971 *Price Supp. A* 35
- 306 TRYGVE AARUM Angiography in acute mechanical obstruction of the small intestine 1971 *Price Supp. A* 40
- 307 PERTTU MITTALA Effect of dimethyl sulfoxide (DMSO) on cytoplasmic barrier of malignant epidermal cells—An investigation in skin tumor resistant mice 1971 *Price Supp. A* 35
- 308 JORGEN RYLAND Mechanism of blood clearance of colloidal gold in mice—An atomic clinical investigation using activation analysis 1971 *Price Supp. A* 35
- 309 LAURI PATOMAKI A mathematical model for radiation fields of telecobalt treatment units—With special reference to the models of Røed 1971 *Price Supp. A* 35
- 310 RADIOLOGICAL INVESTIGATIONS Edited by Erik Lundgren and Bernhard Tribula 1971 *Price Supp. A* 45
- 311 HAL OR VERLUND Enhancement of radiation effects by chemotherapy 1971 *Price Supp. A* 35
- 312 PERTTU KASKI Osteomedullography of the tibia 1971 *Price Supp. A* 40
- 313 PROCEEDINGS OF THE SIXTH CONFERENCE OF THE NORDIC ASSOCIATION OF CLINICAL PHYSICISTS held in Århus, Denmark 1970 Edited by C. B. Madsen and K. Liden 1972 *Price Supp. A* 45
- 314 BERGER HELLY Heart volume in human kidney transplantation 1972 *Price Supp. A* 25
- 315 URS WEGELIN Angiography of the hand. Clinical and postmortem investigation 1972 *Price Supp. A* 35
- 316 P. E. S. PALMER Haemangiosarcoma of Kaposi 1972 *Price Supp. A* 35
- 317 JUHANI RAUTIA Lymphographic findings in granulomatous inflammations and connective tissue diseases—Differential diagnosis between the diseases and lymphomas 1972 *Price Supp. A* 30
- 318 OVE NITTHOM Formation of the tomographic image—With special reference to blurring 1972 *Price Supp. A* 35
- 319 PROGRESS IN VETERINARY RADIOLOGY Proceedings of the 2nd International Conference of Veterinary Radiologists held in Stockholm 1970 Edited by Sten Erik Olsson 1972 *Price Supp. A* 45
- 320 TJAERO KUTIPKIS Carcinoma of the uterine cervix. Aspects of clinical oncology in patients referred for radiation therapy 1972 *Price Supp. A* 50
- 321 BO LUNDSTROM Angiographic abnormalities following percutaneous needle biopsy of the kidney 1972 *Price Supp. A* 40
- 322 LARS BLUMQVIST Mode of accumulation of iodophenylalanines in the exocrine pancreas and certain tumours 1972 *Price Supp. A* 40
- 323 INGEBRIGT RADLOGIC reporting 1973 *Price Supp. A* 40
- 324 TIMO TELARANTA The role of host tissue in skin carcinogenesis—An investigation with skin tumor resistant and skin tumor susceptible mice 1973 *Price Supp. A* 35
- 325 NILS GUNMAR LUNDQVIST Accumulation of drugs on melanin 1973 *Price Supp. A* 40
- 326 JOHAN ERIC JOHANSSON Hystero-graphy and diagnostic curettage in carcinoma of the uterine body 1973 *Price Supp. A* 40
- 327 ERIC BERQVIST Tentorial notch and adjacent major vessels in carotid angiography 1973 *Price Supp. A* 45

- 328 O HAMLÉN and S O HILTALA Angiographic abnormalities in the urinary bladder wall after irradiation. Part I. Animal experiments. Part II. Clinical investigation. 1973. Price Sw. Kr. 45.
- 329 OLAV FOSYDAL Tomography of the temporomandibular joint—Correlation between tomographic image and histologic sections in a three-dimensional system. 1973. Price Sw. Kr. 40.
- 330 JORMA RANTANEN Radiation injury of connective tissue—A biochemical investigation with experimental granuloma. 1973. Price Sw. Kr. 40.
- 331 FRANZ PAUL PROBST Congenital defects of the corpus callosum—Morphology and cephalographic appearances. 1973. Price Sw. Kr. 50.
- 332 GUDR Y ALM CARLSON Dosimetry at interfaces—Theoretical analysis and measurements by means of the thermoluminescent LiF. 1973. Price Sw. Kr. 40.
- 333 MATTI VALIO Postoperative coronary angiography. 1973. Price Sw. Kr. 40.
- 334 I JOHANSSON, A SANDRI and H L KOTTWITZ Carcinoma of the uterine corpus. A retrospective survey of individualized therapy. 1973. Price Sw. Kr. 40.
- 335 METZGERMAN A NON IONIC WATER SOLUBLE CONTRAST MEDIUM—I. Experimental and preliminary clinical investigations. 1973. Price Sw. Kr. 50.
- 336 SYLV SCHILLER and LARS MÅRTENSON Traumatic dislocation of the patella. A radiographic investigation. 1974. Price Sw. Kr. 50.
- 337 Ossi HORSJOLA Myocardial scintigraphy and estimation of regional blood flow with xenon-133. 1974. Price Sw. Kr. 40.
- 338 HURT ÅSTRAND and SYLV REICHMANN Optimized tomography. Theoretical and practical analysis of the minimization of depiction errors in tomography. 1974. Price Sw. Kr. 40.
- 339 ILKKA S RÄMÖ Lymphography in tuberculosis. 1974. Price Sw. Kr. 40.
- 340 EVA NORDSTRÖM ^{75}Se sodium selenite scintigraphy in diagnosis of tumours. 1974. Price Sw. Kr. 45.
- 341 ILPO LAAITYLÄ Telemetry with image intensifier camera. A low radiation dose method. 1974. Price Sw. Kr. 50.
- 342 ANDRÉ MOLLER Pneumography in paraventricular and intraventricular tumours of the posterior fossa. 1974. Price Sw. Kr. 60.

WATER SOLUBLE CONTRAST MEDIA AND ADHESIVE ARACHNOIDITIS

II Reinvestigation of operated cases

L. IRSTAM and M. ROSENCRANTZ

Adhesive arachnoiditis after lumbar myelography with Pantopaque has been described as rare (e.g. HARVEY & FREEMAN 1963) although extensive reactions have been reported (DAVIES 1936 FISHER 1963 SHAPTELO 1968 and others). The condition has also occasionally been reported after lumbar myelography with various water soluble contrast media, a causal relationship between the medium and the arachnoiditis has sometimes been obvious but sometimes only possible.

AUTIO et coll (1972) described adhesive arachnoiditis at repeat myelography of 6 patients primarily examined with methylglucamine iothalamate (Conray 60) but no reaction in 12 patients primarily examined with methiodal (Kontrast U). None of the patients had been operated upon between the first and second myelographies. The lesions were not verified pathologically in 5 of the 6 patients with radiologic changes suggesting adhesive arachnoiditis. The 11th patient died later from a malignant disease. At autopsy the spine was removed en bloc, despite careful dissection no changes could be demonstrated in the meninges and microscopy failed to reveal any signs of arachnoiditis (AUTIO 1972).

From the Department of Diagnostic Radiology II (Director Prof I Wickbom), Sahlgrenska sjukhuset 413 45 Gothenburg, Sweden. Submitted for publication 29 December 1972.

Table 1

Frequency of adhesive arachnoiditis

Contrast medium from first examination	Patient operated upon after first examination			Patient not operated upon after first examination		
	Total	With adhesive arachnoiditis		Total	With adhesive arachnoiditis	
Kontrast U	30	39	79	32	10	31
Conray 60	3	1	33	3	0	0
Dimer X	12	5	42	7	0	0

The frequency of adhesive arachnoiditis following myelography with various water-soluble contrast media was the subject of a recent article (IRSTAM & ROSENCRANTZ 1973) the patients had not been operated upon before repeat myelography.

It is known that adhesive arachnoiditis may occur in patients who have been operated upon before a myelography. The changes may be so severe as to be difficult to distinguish from those due to herniation of a vertebral disc. The myelograms of patients who had been operated upon before repeat myelography have been reviewed in order further to elucidate their pathogenesis.

Material and Methods. The primary material is identical to that described in part I. It consisted of 856 patients primarily examined with Kontrast U (Group I), 152 primarily with Conray 60 (Group II) and 500 patients primarily with Dimer X (Group III). Fifty patients of Group I, 3 of Group II and 12 of Group III were operated upon shortly after the first examination and were re-examined after a varying interval. There were 14 patients in Group I and 2 in Group III who were also examined a third time; of these latter 16 patients 6 were reoperated upon after the second myelographic examination. Kontrast U having been used also for the second examination in 5 patients and Dimer X in one patient (Table 6). Two further re-examined patients from Group I were excluded since the films were missing.

The myelographic technique has been described in detail previously (IRSTAM *et al.* 1970; IRSTAM & ROSENCRANTZ 1973). The patients were first examined lying on the affected side, then prone and finally on the opposite side. The amounts of medium used were 10 to 12 ml Kontrast U, 5 ml Conray 60 mixed with 2 to 4 ml of CSF, or 4 to 5 ml of Dimer X mixed with an equal volume of CSF.

Table 2

Changes in caudal root pockets

Contrast medium at first examination	Patients operated upon after first examination with adhesive arachnoiditis		Patients not operated upon after first examination with adhesive arachnoiditis	
	S3	S2	S3	S2
Kontrast U	37	74	10	31
Cortray 60	1	33	0	0
Dimer X	5	42	0	0

The interpretation was mainly the same as in part I. The following changes were thus recorded:

(A) Impaired filling of root pockets graded as follows: Grade 1 — Incomplete filling on one side, normal on the other; Grade 2 — Incomplete filling on both sides; Grade 3 — No filling on one side, normal on the other; Grade 4 — No filling on one side, incomplete on the other; Grade 5 — No filling on either side.

(B) Abnormalities in the appearances of the cul de sac, its position in the spinal canal as well as of the visibility of nerve roots in the caudal part of the subarachnoid space.

(C) Root pocket cysts: the extent to which they were filled, and their appearances.

In addition to these criteria the post-operative deformation had to be interpreted and—if possible—a distinction made between these changes and those caused by adhesive arachnoiditis.

Results

The frequency with which myelographic changes of adhesive arachnoiditis appeared between first myelography and repeat myelography appears in Tables 1 to 5.

Root pockets. Changes were evident in the root pocket of S3 in 37 patients of S2 in 37, of S1 in 28 and of L5 in 15 patients in that part of the material primarily examined with the Kontrast U technique. The various types and the distribution of the changes are presented in Table 3.

Repeat myelography disclosed root pocket changes in 1 patient in that part of the material examined with Cortray 60: grade 5 changes were present at the level of S3 and S2, while at the level of S1 the change was grade 3.

Table 1
Frequency of Adhesive Arachnoiditis

Contrast medium used	Patients operated upon		Patients not operated upon		Total	
	Total	With Adhesive Arachnoiditis	Total	With Adhesive Arachnoiditis	Total	With Adhesive Arachnoiditis
Kontrast L	20	37	8	3	10	1
Contrast 60	3	1	33	3	0	
Dimer X	1		4		0	

The frequency of adhesive arachnoiditis following myelography with various water-soluble contrast media was the subject of a recent article IRSTAM & ROSENCRANTZ 1973. The patients had not been operated upon before repeat myelography.

It is known that adhesive arachnoiditis may occur in patients who have been operated upon before a myelography. The changes may be so severe as to be difficult to distinguish from those due to herniation of a vertebral disc. The myelograms of patients who had been operated upon before repeat myelography have been reviewed in order further to elucidate their pathogenesis.

Material and Methods The primary material is identical to that described in part I. It consisted of 806 patients primarily examined with Kontrast L (Group I: 152 primarily with Contrast 60 (Group II) and 500 patients primarily with Dimer X (Group III). Fifty patients of Group I, 3 of Group II and 2 of Group III were operated upon shortly after the first examination and were re-examined after a varying interval. There were 14 patients in Group I and 2 in Group III who were also examined a third time. Of these latter 16 patients 6 were reoperated upon after the second myelographic examination. Kontrast L having been used also for the second examination in 3 patients and Dimer X in one patient (Table 6). Two further re-examined patients from Group I are excluded since the films were missing.

The myelographic technique has been described in detail previously (IRSTAM *et al.* 1970; IRSTAM & ROSENCRANTZ 1973). The patients were first examined lying on the affected side, then prone and finally on the opposite side. The amounts of medium used were 10 to 12 ml Kontrast L, 3 ml Contrast 60 mixed with 2 to 4 ml of CSF or 4 to 5 ml of Dimer X mixed with an equal volume of CSF.

Tabl 2
Changes in caudal root pockets

Contrast medium used at first examination	Patients operated upon after first examination with adhesive arachnoiditis		Patients not operated upon after first examination with adhesive arachnoiditis	
Kontrast U	37	74	10	31
Couray 60	1	33	0	0
Dimer X	5	42	0	0

The interpretation was mainly the same as in part I. The following changes were thus recorded:

(A) Impaired filling of root pockets graded as follows: Grade 1 — Incomplete filling on one side, normal on the other; Grade 2 — Incomplete filling on both sides; Grade 3 — No filling on one side, normal on the other; Grade 4 — No filling on one side, incomplete on the other; Grade 5 — No filling on either side.

(B) Abnormalities in the appearances of the cul-de-sac, its position in the spinal canal as well as of the visibility of nerve roots in the caudal part of the subarachnoid space.

(C) Root pocket cysts: the extent to which they were filled and their appearances.

In addition to these criteria the post-operative deformation had to be interpreted and—if possible—a distinction made between these changes and those caused by adhesive arachnoiditis.

Results

The frequency with which myelographic changes of adhesive arachnoiditis appeared between first myelography and repeat myelography appears in Tables 1 to 5.

Root pockets. Changes were evident in the root pocket of S3 in 37 patients of S2 in 37 of S1 in 37 and of L5 in 15 patients in that part of the material primarily examined with the Kontrast U technique. The various types and the distribution of the changes are presented in Table 3.

Repeat myelography showed root pocket changes in 1 patient in that part of the material examined with Couray 60; grade 5 changes were present at the level of S3 and at the level of S1 the change was grade 3.

Table 3

Caudal root pocket later on self taking film

Series	Root pocket changes			
	S3	S4	S1	L5
Control	3	8		1
Contray	0	0	3	
Cul-de-sac	1	14	10	8
Control 4	3	4	3	3
Control 5	10	11	3	1

Repeat myelography revealed root pocket changes in 5 patients in that part of the material examined with Dimer X and afterward operated upon: in one of these grade 5 changes were present at the level of S3 and S4; in another case there were grade 3 changes at the level of S3 and grade 4 changes at S4. In the third patient grade 2 changes were evident at the level of S3 and S4 while in the fourth patient the changes were of grade 1 and situated at the level of S3, S4, S1 and L5. The fifth patient is described below.

Cul-de-sac. The cul-de-sac was deformed equally often in all 3 groups. Table 4—its evaluation in the Contray and Dimer X techniques must be made with caution because the materials were so small.

All the patients in the Kontrast U and Contray 60 materials with deformation of the cul-de-sac also had coexisting changes of the root pockets and reduced definition of the nerve roots in the caudal part of the subarachnoid space. The cul-de-sac in the Dimer X material was deformed in 5 patients including 4 with involvement of several root pockets. Repeat myelography in the fifth patient revealed that the caudal part of the subarachnoid space was much narrower than at the primary examination. The nerve roots and root pockets on one side had ordinary appearances. On the other side where the patient had been operated upon in the meantime for herniation of a vertebral disc at the level of L5—S1 a postoperative deformation was present. Repeat myelography produced normal filling of the root pockets of L5 and S1 while that of S2 was defective as in adhesive arachnoiditis.

Table 4

Changes in the cul-de-sac

Contrast medium at first examination	Patients operated upon after first examination with arachnoiditis	Patients not operated upon after first examination with adhesive arachnoiditis
Kontrast U	1	4
Contrav 60	1	33
Dimer X	4	0

Table 5

Changes in root pocket cysts

Contrast medium at first examination	Patients operated upon after first examination with adhesive arachnoiditis	Patients not operated upon after first examination with adhesive arachnoiditis
Kontrast U	10	26
Contrav 60	0 0	0
Dimer X	1 4	0 1

Irrespective of the type of contrast medium used for the preoperative myelography in all patients in whom the root pockets had been only partly filled or not filled at all at repeat myelography the corresponding nerve roots were less distinctly outlined. When two or more consecutive root pockets were involved the impaired definition of the nerve roots varied with the extent of the process in the root pockets. When changes occurred bilaterally in the entire cul-de-sac no nerve roots could be identified in that part of the subarachnoid space. As previously reported (IRSTAM & ROSENCRANTZ) patients who were subjected to repeat myelography without having undergone any operation in the meantime had changes extending around the nerves in the subarachnoid space adjacent to the origin of the root pockets. In all patients in whom no adhesive arachnoiditis was demonstrable the definition of the roots was normal at both examinations.

Root pocket cysts Root pocket cysts were demonstrated at primary myelography of 10 patients examined with Kontrast U. In 3 of these the cysts were bilateral and in 2 of these 3 patients no filling of the root pocket cysts was obtained at repeat myelography. In the first of these latter 2 patients no filling was obtained either of the root pockets of S3 and S2 or of one of the root pockets of S1 while the filling of the other S1 pocket was less than at the primary

Tabl 6

Patients examined by myelography more than once. Filling in the left half of the table denotes filling at the first repeat myelography and in the right half at the second repeat myelography.

Procedure	No. of patients	Patient with haematoma	Level of filling	Patient with filling	Patients with accentuated filling
Myelogram			Myelogram		Repeat myelogram
Kp	4	3	KpK	4	
Kp		1	KjC		0
Kp		1	KpD		1
Dp		1	DpD	1	1
Kp	4	4	KpKp	4	4
Kp	1	1	KjDj	1	0
Kj p	1	1	Kj j Kp	1	1
K lumbar	myelogram	performed with K	1		
E lumbar	myelogram	performed with C or G			
D lumbar	myelogram	performed with D			
p	perforated disc hernia	performed after			
p	perforated disc hernia	after surgery			

myelography. The pocket of one of the roots of L₅ situated on the side on which the root pocket of S1 remained unfilled was only partly filled at repeat myelography, while the opposite L₅ root pocket appeared normal, the cul-de-sac also appeared normal. In the second patient root pocket cysts were present adjacent to the root pockets of S3 at the primary examination. However these cysts could not be demonstrated at repeat myelography, which revealed a defective filling of the root pocket of S3 on one side and no filling at all of the corresponding root pocket on the other side; the cul-de-sac appeared normal.

Filling of a cyst adjacent to one of the root pockets of S² or S3 was obtained at primary myelography in 3 patients. These root pockets were at most partly filled at repeat myelography and the corresponding root pocket cysts were unfilled.

No filling was obtained of root pocket cysts at any of the examinations in the Conray 60 material.

Root pocket cysts were present at the primary lumbar myelography in 4 patients in the Dimer X material including 1 with bilateral changes; only in that patient no filling at all was obtained of root pocket cysts at the second myelography. At the same time the filling of the pockets of S3 and S2 roots was defective and the cul-de-sac was deformed; this was strikingly narrow and hour glass in shape. In addition to these patients in whom the absence of filling of

Table 7

Postoperative deformation of the subarachnoid space

Contrast medium at first examination	% of patients examined	% of patients with deformation
Kontrast U	30	20 40
Conray 60	3	2 (67 %)
Dimer X	12	3 (25 %)

the root pocket cysts at repeat myelography was readily recognized from other changes suggesting extensive adhesive arachnoiditis, 2 patients had a somewhat paradoxical filling of root pocket cysts. These 2 patients had primarily been examined with Kontrast U, had been operated upon for herniation of a vertebral disc and had afterwards been re-examined with Dimer X because of recurrent symptoms. Filling was obtained at the primary examination of a cyst of one of the root pockets of S3 in one of these patients; no further root pocket cyst could be demonstrated. The second examination indicated filling of the same cyst at the level of the root pocket of S3 although the filling of the pocket itself was poor. Outlining was also obtained of cysts of the contralateral root pockets of S1, S2 and S3 at the second myelography in spite of the fact that the root pocket of S3 on that side was only partly filled.

Primary myelography in the second patient had revealed filling of a root pocket cyst at the level of one of the S3 root pockets but no further root pocket cyst could be demonstrated. No filling was obtained of the root pockets of S3 and S2 on that side at repeat myelography. The cul de sac was narrow and hour glass in shape while the nerve roots in the cul-de-sac could not be identified. The root pocket cyst filled at primary myelography was not outlined at the second myelography but filling was obtained of a root pocket cyst in connection with the contralateral S2 and S3 root pockets in spite of the fact that the root pocket of S2 was just partly filled, the S3 pocket not at all.

The primary examination was technically satisfactory in these cases; the contrast concentration was acceptable and judging from the good definition of minor details in the myelogram filling of any of the root cysts would have been recognised.

Discussion

None of the patients of repeat myelography at the first exami-

our previous series (IRSTAM & ROSENCRANTZ 1973) without operation had signs of primary arachnoiditis.



Fig 3

Fig 4

Fig 3 a) Disc herniation at L5—S1. Verified at operation. b) Two years later repeat myelography indicated herniation at L4—L5. The cul-de-sac was shorter than in a) root pockets below the herniation ill defined. Operation at level of L4—L5 revealed bulging disc but no true herniation; the disc was incised but no sequestrum was evident. c) Three years later 11 cm long defect above and below L4—L5. The cul-de-sac was completely obliterated at the middle of L5 and no nerve roots could be identified below L4—L5. Further operation revealed herniation but no extradural adhesions; the level below L4—L5 was not explored.

Fig 4 a) Primary myelography. Operation revealed herniation at L4—L5. b) Repeat myelography revealed total and irregular obliteration of the cul-de-sac at L4—L5; the nerve roots just above the block poorly outlined. Further operation revealed extradural adhesions and a mild adhesive arachnoiditis but no disc herniation (Case 2).

herniation as well as a new deformation of the most cranial part of the cul-de-sac. The root pockets and the rest of the subarachnoid space were unchanged. The recurrent hernia was operated upon and the patient afterwards felt well and had no neurologic signs. Judging from these two series primary adhesive arachnoiditis is rare and can seldom play a role in the cause of changes appearing at repeat myelography.

The interval between the first and the second examination with Kontrast U

was 6 to 110 months (average 17 months). This interval was much longer than that in our former series in which it was 15 months. The interval between the first and the second examination of the 3 patients who were examined first with Conray 60 ranged from 10 to 19 months (average 15 months). In the unoperated material in which none of the patients examined first with Conray 60 had adhesive arachnoiditis, the corresponding mean interval was 11 months. The interval between the examination was 11 months (range 2 to 10 months) in those patients examined and re-examined with Dimer X. The corresponding figures were 16 months and 10 to 23 months in the unoperated material.

No statistically significant correlation was evident in the present operated material as in the unoperated material between the frequency, spread and severity of the adhesive arachnoiditis and the interval between the examinations. The material would not permit any conclusions as to the time necessary for adhesive arachnoiditis to develop after myelography. The interval between the examination was fairly long and never less than two months.

It is clear from the accompanying tables that the frequency of adhesive arachnoiditis was notably higher when the patients had been operated upon between the two examinations. This finding should however be interpreted with caution. It should be borne in mind that at least as far as Kontrast U is concerned the interval for the unoperated patient was much shorter than for those who had been operated upon in the meantime. This however is of less importance because no correlation was evident between the interval between the examinations and the occurrence of adhesive arachnoiditis. In the two different materials the interval between the two examinations in the Kontrast U group on one hand and the Conray 60 and Dimer X groups on the other was very different.

In the evaluation of the differences in frequency and severity it should be remembered that the Conray 60 and the Dimer X series were small. The frequency of adhesive arachnoiditis after lumbar myelography with Kontrast U was 31 per cent in the unoperated material and 78 per cent in the operated material, i.e. a difference of 47 per cent. The corresponding differences in the Conray 60 and the Dimer X groups were 33 and 42 per cent respectively. The main difference between the unoperated re-examined group and the operated re-examined group was the operation per se. It appears reasonable to assume that operation causes adhesive arachnoiditis of varying severity with a frequency of about 30 to 40 per cent.

Repeat myelography in 35 of the patients in the present material revealed disc herniation in a different localization compared to the first herniation. The frequency of arachnoiditis among these 35 patients did not differ significantly from that in the rest of the material irrespective of the type of contrast medium.

med at the first examination. Neither was any significant difference found in the frequency of arachnoiditis between the patients in the group with herniation of a vertebral disc and the remainder. The changes observed decreased in frequency in a cranial direction, irrespective of medium administered. If absence of filling of root pockets be regarded as the greater change and partial filling as a less severe one, it would mean that the lesions decreased in severity in a cranial direction. Although asymmetric these changes were always more marked on the affected side i.e. where the concentration of medium had been the highest.

Even though the material primarily examined with Conray 60 or with Dimer X and afterwards operated upon was small the extent and degree of the changes in the root pockets were the same as those after myelography with Kontrast U and subsequent operation. The results are also in full agreement with those that occurred in the previous material in which repeat myelography was performed without preceding operation.

The changes were relatively small in the 6 patients with deformation of the cul de sac after lumbar myelography with Conray 60 or Dimer X and subsequent operation. Several of the 21 patients with deformation of the cul de sac after myelography with Kontrast U likewise prevented mild deformation. In this part of the material there were also a few patients with advanced deformation of the subarachnoid space. It is possible that these cases of marked adhesive arachnoiditis occurred only in the larger series owing to statistical variation. There is however reason to infer that the advanced deformation of the most declive part of the subarachnoid space was more common after lumbar myelography with Kontrast U than following myelography performed with any of the other contrast media used.

It was always noted how far down the spinal canal the subarachnoid space was demonstrable. Neither the presence nor the severity of adhesive arachnoiditis varied with the extent to which the cul de sac extended down the spinal canal irrespective of the type of medium used at the first examination.

It is not known why the filling of root pocket cysts and occasionally the filling of the root pockets in the cul de sac as well varied from the first to the second examination. It is possible that sometimes the adhesive arachnoiditis was due to loose fibrous strands in the subarachnoid space. A root pocket and that part of the subarachnoid space just before its origin might be partly shut off from the normal circulation of the CSF. Owing to possible openings and passages between the fibrous strands it is possible that a small amount of contrast medium might have passed out into a root pocket cyst without filling the corresponding pocket.

Once it had been realised that adhesive arachnoiditis is so common all the reports of the first operation were carefully examined. The operator had nearly

It was noted whether any substantial extradural bleeding or not had occurred. No correlation was proved between the presence of extradural bleeding and the occurrence of adhesive arachnoiditis. The surgeon had recorded that at three operation he had accidentally made a small pit in the dura in none of these patients was adhesive arachnoiditis observed at repeat myelography. The frequency of arachnoiditis did not vary with the operator neither was any difference recorded in frequency or severity of arachnoiditis between patients or skulls explored at one or more level on one or both sides. The surgeon's report of the second operation in the re-operated cases were also analysed it was usually stated whether extradural adhesion had been present or not. There was no correlation between the presence or absence of extradural adhesions and the existence or severity of adhesive arachnoiditis myelographically demonstrated.

The findings at operation after the first myelographic examination in 12 of the 63 patients was herniation of a disc. Of these three were free fragments which in 2 patients were displaced laterally in the spinal canal and in 1 patient medially. The affected disc in 7 patients was not herniated but protruded. The operation findings in 6 patients varied e.g. vertebral exostoses bulging into the subarachnoid space, oedematous nerve root with surrounding extradural scar formation. Exploration had revealed no pathologic findings in another 7 patients.

The picture of the findings at myelography listed postoperative scar formation often occurred (Table 7). The deformation of the subarachnoid space extended both above as well as below the disc explored. The opinion of CROQVIST (1959) that postoperative deformation only at the level of the disc indicates a recurrence of a herniation while scar tissue has a tendency to produce deformation extending somewhat above and below the disc explored was fully appreciated in the retrospective evaluation of the films. CROQVIST's postulation could however not be confirmed in spite of the fact that the results of further operation were known.

The observation by LUNDQVIST (1951, 1953) that the myelographic changes produced by recurrent herniation of a disc is often situated further ventrally than a postoperative deformation was sometimes verified but such a finding is by no means the rule. Most patients who really had recurrent herniation of a disc also presented postoperative deformation in the ventral part of the subarachnoid space. It would therefore appear that it is usually not possible myelographically to distinguish between postoperative deformation and recurrence of disc herniation. These extradural changes that complicate the interpretation of postoperative myelograms must be added to those caused by adhesive arachnoiditis. As pointed out, these changes may be marked partly or completely obstructing the subarachnoid space and thereby simulate recurrent herniation of the disc or postoperative deformation by extradural scar formation.

With the examination technique used the expansion of the cul de sac appears to vary somewhat with the extent to which the headend of the examination couch is raised. This should be borne in mind in the evaluation of deformation if any of this part of the subarachnoid space. Isolated deformation of the cul de sac without simultaneous root pocket changes and decreased visibility of nerve roots has however never been encountered. Autio was unable to demonstrate adhesive arachnoiditis in the one case in which autopsy was performed. The dura was surgically opened for direct inspection in 2 of the present cases.

Case 1 Woman aged 52 in whom the first myelography examination performed with contrast U revealed typical changes of left-sided herniation of the L4—L5 disc. This was confirmed at operation at which the corresponding area on the right side was also explored with negative results. Owing to recurrent symptoms the patient again underwent operation 41 months later at the same level and without repeat lumbar myelography. Massive extradural adhesion as well as two small herniation residues were present on the left side. Complete laminectomy of L5 and partial laminectomy of L4 were performed.

The patient had recurrent symptoms and was re-examined with contrast U two years later i.e. 65 months after the first myelographic examination. The cul de sac which at the first examination extended down to the level of the lower margin of S1 was now filled with contrast medium to the lower margin of L5 and was caudally rounded with a somewhat irregular outline. No nerve roots could be identified below the middle of L5 and no root pockets demonstrated at or below this level. The dura at further operation had evidence of adhesive arachnoiditis: biopsy of the adhesion revealed cicatrised sclerosed connective tissue with some small vessels, particles of blood pigment and infiltrates of round cells i.e. scar tissue.

Case 2 Woman aged 48. The first lumbar myelography with contrast U revealed changes suggesting herniation of the disc at L4—L5 but no other abnormality. The caudal end of the subarachnoid space was demonstrable down to the upper margin of S1. Bilateral surgical exploration at this level of the possible herniation of the disc revealed nothing of interest. The dura was opened and the filum terminale was found to be much thickened. Since no other changes that could explain the severe coccygodynia were present the roots were partly divided by diathermy. The condition of the patient failed to improve and 14 months later myelography by the same method was repeated. This time the subarachnoid space proved to be completely obstructed at the level of the upper margin of L5. Surgical exploration disclosed a small extradural cyst which was interpreted as meningocele sparium. No herniation was evident. The dura was re-opened and extensive arachnoiditis particularly caudally was now present. Biopsy indicated chronic inflammation (Fig. 4).

The changes described were evidently of the same nature whether operation had been performed or not and were due to adhesive arachnoiditis. There appeared to be no doubt that the changes following myelography alone are due to the chemical or toxic effects of the contrast medium and possibly the spinal anaesthetic. The distribution and the severity of these changes varied with the local concentration of the medium in the subarachnoid space. The exposure time which was longer when larger volumes of contrast medium were used

might also have been of importance. This assumption is supported by the report of AHLGREN (1972) of a much higher frequency of adhesive arachnoiditis in patients examined with Conray 60 or Dimer X and in whom the volumes of contrast medium used were larger than in the present material.

The mechanism for the changes due to surgery must be explained in some other way since the dura is usually not opened during the operation. The most probable explanation seems to be circulatory changes secondary to bleeding or to thrombosis of small vessels. This mechanism may also contribute to the changes following myelography, at least if the puncture is complicated by bleeding. Lesions of this kind may also enhance the irritating effect of the contrast medium. A supposition supported by the high frequency of changes in repeat myelography following operation (Table 6).

SUMMARY

The present investigation suggests that lumbar myelography with methiodal (Kontrast U) after preceding spinal anaesthesia is more likely to produce adhesive arachnoiditis than myelography with methylglucamine iohalamat (Conray 60) or iohexol (Dimer X). Furthermore, it appears that operation per se for herniation of the lumbar disc has a definite risk of causing arachnoiditis irrespective of the type of contrast medium used in the prior myelography.

ZUSAMMENFASSUNG

Die vorliegende Untersuchung deutet darauf hin, dass die Lumbalmyleographie mit Methiodal (Kontrast U) nach vorangehender Spinalanästhesie mit grosserer Wahrscheinlichkeit eine adhäsive Arachnoiditis hervorruft als die Myleographie mit Methylglucaminiohamat (Conray 60) oder Iohexol (Dimer X). Ausserdem scheint eine Operation per se wegen der Hernienbildung des betroffenen Discus zu klaren Risiko für eine adhäsive Arachnoiditis unabhängig vom Typus des bei der vorangehenden Myleographie benutzten Kontrastmittels mit sich zu bringen.

RÉSUMÉ

Ce travail de recherche fait penser que la sacroradiculographie lombaire avec le méthiodal (Kontrast U) après rachianesthésie doit probablement entraîner plus souvent une arachnoidite adhésive que la sacroradiculographie avec le méthylglucaminiohamat (Conray 60) ou l'iohexol (Dimer X). De plus, il semble que l'opération en elle-même pour hernie d'un disque atteint comporte un risque certain d'arachnoidite adhésive quel que soit le type de moyen de contraste utilisé dans la sacroradiculographie préalable.

REFERENCES

- AHLGREN P. Postmyelografiske eller postoperative arachnoiditiske forandringer efter Conray 60 og Dimer X myelografier (In Danish) Paper read at the Danish Radiological Soc. Meeting in Copenhagen, Denmark Oct. 27th 1972.

AUTO E. Personal communication (1972)

— SJÖLUND J. NORRBACK B. and SLATHS P. Adhesive arachnoiditis after lumbar myelography with meglumine iohalamate (Conray) Acta radiol. Diagnosis 12 (1972) 17

CRÖNGER S. The postoperative myelogram Acta radiol. III (1959) 45

DAVIS F. L. Effect of unabsorbed radiographic contrast media on the central nervous system Lancet 2 (1956) 747

FISHER R. L. An experimental evaluation of pantopaque and other recently developed myelographic contrast media Radiology 85 (1963) 537

HARVEY J. P. and FREIBERGER R. H. Myelography with an absorbable agent J. Bone Jt. Surg. 47 A 2 (1965) 397

IRSTAM L. LÖNNERHOLM T. SUNDSYÖW R. och ZARNOFF M. Lumbal myelografi med Conra Meglum 282 (In Swedish) Lakartidningen 67 (1970) 3183

— and ROSENCRANTZ M. Water soluble contrast media and adhesive arachnoiditis. I. Reinvestigation of nonoperated cases Acta radiol. Diagnosis 14 (1973) 497

LEHMANN E. Myelographie I. Lehrbuch der Röntgendiagnostik 5. Aufl. 1501 Herausgegeben von H. R. Schinz, W. E. Baensch, Friedl. und E. Uehlinger Georg Thieme Stuttgart 1951

— Röntgenologie. In: Handbuch der Neurochirurgie Bd 2 Herausgegeben von H. Olivecrona und W. Tonnus Springer Berlin 1954

SLATER R. Myelography Second edition Year book medical publishers Inc. Chicago 1968

SODERBERG L., SJÖSTRÖM S. and LANGEZAND E. Neurological complications following myelography with water soluble contrast medium Acta orthop scand 28 (1968) 220

POST OPERATIVE PSEUDODISCICULI (SPURIOUS MENINGOCILI) OF THE CERVICAL SUBARACHNOID SPACE

Y. W. HUI, JUNE DEBOER LACER and P. J. CRISWELL

Cist myelography is in our opinion the best method to determine the level of cord involvement and extent of adjacent bone or soft tissue alteration before surgical procedures in order to ameliorate cervical myelopathy due to spondylosis. It also provides an excellent means of assessing the post-operative status of the cord and subarachnoid space. By means of this procedure we have been able to demonstrate pseudodisciculi of the cervical subarachnoid space in nineteen out of twenty-one following surgery.

Materials and Methods Cist myelography was performed both pre and post operatively in twenty-one patients with cervical spondylosis and myelopathy. The technique used was similar to that described by ROTH (1963) and LEHIA & RABBELO (1967) employing a single lumbar subarachnoid puncture with removal of approximately 40 ml of cerebrospinal fluid before injection of a corresponding amount of humidified oxygen. Tomography was accomplished

Submitted for publication 30 July 1972



Fig 1 Lateral gas myelograms from two cases one month following laminectomy and dentate section. a) Large air-filled sac extending into the cervical soft tissues for the length of almost five cervical vertebrae. b) Small pseudomeningocele appearing continuous with the posterior subarachnoid space opposite C7.

utilizing the hypocycloidal trajectory of the Polytome Surgery in all instances consisted of posterior laminectomy and dentate ligament section. In nine cases outpouchings of the posterior cervical subarachnoid space were demonstrated approximately one month post-operatively. These structures were variable in size ranging from one cm in diameter to 4 cm \times 9 cm in transverse and axial dimensions and occasionally protruded for some distance into the soft tissues of the neck (Figs 1a-2). Six of the patients had uneventful post-operative courses. The remaining three however developed unexpected clinical symptoms and signs which consisted of low grade fevers ranging from 20 to 40 days in duration unattended by any apparent source of infection, and posturally induced syncope and headache. The latter were particularly marked when arising from the supine position and unassociated with any alteration in blood pressure. The following case is illustrative.

Case Report

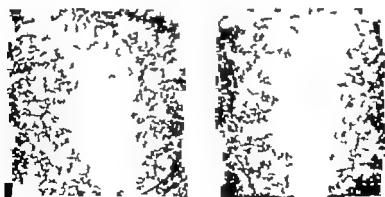
A 38-year-old man was admitted following fall coincident with sudden loss of sensation in his right leg and hand. He denied any symptoms before the incident. Neurologic examination revealed weakness of the right biceps, triceps and intrinsic muscles of the right hand. Right upper and lower extremity reflexes were spastic and unsustained. Babinski's sign and a positive Hoffmann sign were present. Hyperactive reflexes were present on the left and hyperesthesia along the sixth cervical dermatome was noted. No intracranial abnormalities were found.

Gas myelography revealed a narrow cervical canal aggravated by soft tissue thickening at the level of the third cervical interspace. Laminectomy from C3 through C6 was performed combined with dentate ligament section. This was followed by definite improve-



a

Figure 5a shows a cross-section of the material. The dark mass on the left is likely the lateral face of the specimen, which was subjected to a high-temperature treatment. The lighter region on the right is the interior of the specimen, which was not directly exposed to the treatment. The boundary between the two regions is irregular, suggesting a complex internal structure or a reaction between the treated and untreated areas.



b

Fig. 5. Scan performed 30 minutes following sulfur-richness insulation of RISA and technetium alluminum. (a) Later (b) (cf. with Fig. 9b).

went in the neurologic signs but the post-operative course was complicated by fever probably induced headache and occasional syncope.

A repeat gas myelography one month following surgery demonstrated a 5 cm \times 6 cm \times 8 cm gas filled sac continuous with and extending from the subarachnoid space into the posterior cervical soft tissues (Fig 2 a, b). In order to further document the communication and to provide a base line for later examinations 2 mCi of technetium albumin combined with 100 μ Ci of RISA were introduced into the lumbar subarachnoid space. Scans of the cervical area (Fig 3) were taken at 30 minutes, 24 and 48 hours. The isotope activity was highest at 30 minutes and gradually faded on the later scans.

The symptoms gradually subsided during the second post-operative month and the sac had completely disappeared when it was re-examined 3 months following surgery (Fig 2 c). Repeat isotope scanning at this time also failed to demonstrate the lesion.

Discussion

The occurrence of cyst like communications with the subarachnoid space following lumbar laminectomy has been described by others and variously designated as post-operative meningoceles, meningeal pseudocysts or spurious meningoceles. WINKLER & POWERS (1930), BORGSTROM (1934), KETTLER (1956) and RENALDI & PEACH (1969) have suggested that these structures are true meningoceles and either the result of herniation of arachnoid membrane or consequent arachnoid proliferation through a rent in the dura. In a case reported by PAGNI *et coll* (1961) however there was no evidence of arachnoid herniation. A tear in both the subarachnoid and dura provided the route for egress of cerebrospinal fluid into para vertebral planes. Connective tissue response subsequently provided a lining for the pseudocystic cavity. Further histologic evidence that this occurs was provided by MILLER & ELDER (1968) who presented ten cases with similar lesions.

Whereas it is entirely possible that true meningoceles may occur incident to dural perforation we have chosen to regard the nine cases in our series as false or spurious meningoceles. The apparent total disappearance of these structures in three patients within three to six months following surgery suggests that continuing inflammatory reaction may either produce fibrosis and shrinkage of the existing sac or that local tissue proliferation at the communicating point may produce closure followed by eventual resorption of cerebrospinal fluid.

SUMMARY

Nine cases of pseudodiverticula of the cervical subarachnoid space following laminectomy and dental section were reported. Three patients within the group developed unexpected symptoms post-operatively related to the pseudodiverticula. Complete disappearance of these structures followed within six months of the operative procedure.

ZUSAMMENFASSUNG

Neun Fälle eines Pseudotumors des zervikalen Subarachnoidalraums im Anschluss an Laminektomie des Dens-Sektors werden beschrieben. Drei Patienten dieser Gruppe entwickelten unmittelbar postoperative Symptome, die vermutlich mit den Pseudodivertikeln im Zusammenhang stehen. Die übrigen sechs Patienten entwickelten diese Strukturen und innerhalb von sechs Monaten nach der Operation Leichter.

RÉSUMÉ

Neuf cas de pseudotumeur du pseudodiverticule de l'espace sous-arachnoïdien cervical en laminectomie et section du ligament dentaire sont décrits. Trois patients de cette série ont développé des symptômes postopératoires inattendus rassemblés en relation avec les pseudodiverticules. On observe la départition des pseudodiverticules dans les six mois qui ont suivi l'intervention.

REFERENCES

- BORECKROM S. C.: Meningeal pseudocyst following laminectomy and decompression. *Indiana Med J.* 3 (1954) 781.
- FRYDAI C. and RANSON C.: Cerebral spinal fluid cisterna magna injection under pressure. *Radiology* 88 (1967) 917.
- KETTLER H. J.: Eine Meningocele mit Nervenwurzel-Erolaps nach Laminektomie. *Zbl. Chir.* 81 (1956) 313.
- MILLER F. R. and FIDY J. W.: Meningeal pseudocyst: meningeal leptomeningeal following laminectomy. *J. Bone Joint Surg.* 50-A (1968) 761.
- JACOBI C. A., CAMERON A. and BERGMAN A.: Meningocele spurious following hemilaminectomy in case of lumbar discal hernia. *J. Neurosurg.* 18 (1961) 709.
- REYNOLDS I. and JACOBSON W. F.: Postoperative lumbar meningocele. *J. Neurosurg.* 30 (1969) 504.
- ROTH M.: Gas myelography by the lumbar route. *Radiology* 81 (1963) 91.
- WINKLER H. and LOWERY J. A.: Meningeal leptomeningeal following hemilaminectomy. *N. C. M. J.* 11 (1950) 292.

EQUI-OSMOLAL OPENING OF THE BLOOD BRAIN BARRIER IN THE RABBIT BY DIFFERENT CONTRAST MEDIA

§ I RAPOPORT H K THOMPSON and JEANETTE M BIDINGER

Neurotoxicity of contrast media used in carotid angiography may follow opening of the blood brain barrier (BBB) and entry of the media into the brain parenchyma (ROSENTHALL et coll 1969 LAMPE et coll 1970 ALLEN 1971). Severity of the barrier disturbance is related to the concentration of the contrast medium and the period of time in which it acts on the cerebral vessels. Although severity can differ from one contrast medium to another this difference is thought to depend on specific effects of the medium on blood viscosity or on endothelium of the vessels and to be related mainly to the ionic and chemical content of the medium.

Of the many factors that may contribute to BBB damage however solution osmolality is considered relatively unimportant (HARRINGTON et coll 1966 ALLEN 1971). For example BROMAN & OLSSON (1949) and BASSETT et coll (1953) concluded that thresholds for PP₃ damage by different agents were independent of solution osmolality. In this study they compared the effects of glucose NaCl Diatrizoate, Diodone and Umbrellin.

Table

Concentration	Electrolyte	Electrolyte	Electrolyte	Electrolyte	Electrolyte
Medium	N	Ca	Mg	Na	Cl
Angiotensin	1.1.1.1.1	N	1	0.17	0.40
Angiotensin	1.1.1.1.1	Methyl		0	1.8
Angiotensin	1.1.1.1.1	Glucan		0.33	0.49
Angiotensin	1.1.1.1.1			0.17	0
Angiotensin	1.1.1.1.1			1.0	1.43
Angiotensin	1.1.1.1.1	Na	0.8	0.33	0.49
Angiotensin	1.1.1.1.1			0.17	0.99
Angiotensin	1.1.1.1.1			1.0	1.17
Angiotensin	1.1.1.1.1	N	0.1	0.33	0.37
Angiotensin	1.1.1.1.1	Methyl		0.41	0.9
Angiotensin	1.1.1.1.1	Glucan		0.17	1.30
Angiotensin	1.1.1.1.1	Ca	0.01	0.5	0.93
Angiotensin	1.1.1.1.1	N	0.11	0.17	1
Angiotensin	1.1.1.1.1			0.81	1.50
Angiotensin	1.1.1.1.1			1.0	1.8
Angiotensin	1.1.1.1.1	Ca	0.01	0.31	0.41
Angiotensin	1.1.1.1.1	Methyl		0.17	0.94
Angiotensin	1.1.1.1.1	Glucan		0.9	1.4
NaCl	1.1.1.1.1	N		3 g/100 ml	0.94
NaCl	1.1.1.1.1			4 g/100 ml	1.4
NaCl	1.1.1.1.1			5 g/100 ml	1.38

Own data calculated by extrapolation.

The cerebral blood vessel constitute a barrier to exchange of ion and large molecules between brain and blood because they do not have pores between the endothelial cell but only tight junctions (RESE & KARNOVSKY 1967; KARNOVSKY 1968). Physiologic evidence suggests and morphologic evidence confirms that concentrated solutions of electrolyte and relatively lipid insoluble nonelectrolytes such as urea open the BBB reversibly by separating the tight junctions that connect the endothelial cell (RAPOPORT 1970, 1971, 1973; RAPOPORT et al. 1972, 1973; BRIGHTMAN et al. unpublished). The tight junctions probably open when the endothelial cell shrink.

Contrast media in clinical use are as concentrated as solutions that have been shown to open the BBB osmotically. These media may therefore open the tight junctions between cerebrovascular endothelial cells as does urea for example. Such a mechanism would be likely if the media were shown to open the BBB at the same threshold osmolality independently of their chemical or ionic nature.

It therefore was of interest to reexamine the conclusions of ALLEN (1971) BROGAN & OLSSON (1949) and BASSETT *et coll* (1953). We determined thresholds for BBB opening by 6 contrast media which differed in chemical composition, and compared the thresholds to those of NaCl and other agents.

Methods

Nineteen rabbits weighing 1.5 to 2.5 kg were anesthetized with ethyl carbamate (urethan) (1.6 g/kg i.p.). In the last 60 animals blood pressure was recorded with a strain gauge transducer through a femoral artery catheter. The left external and common carotid arteries were exposed and ligated, and the left common carotid was catheterized cephalic to the ligation for brain perfusion (STERNWALL 1958). The skull was trephined and the dura removed over a small region of the left hemisphere in order to observe pial vasculature during perfusion.

Five minutes before perfusion 4 ml/kg of 2% Evans blue/100 ml 0.9% NaCl (Chroma Gesellschaft Schmid and Company Stuttgart) was injected into a catheterized femoral vein. This quantity of dye is bound completely to blood albumin (FREEDMAN & JOHNSON 1969; RAPAPORT *et coll* 1972). Five to 12 ml of test solution was perfused manually for 30 to 40 seconds into the left internal carotid via the common carotid at a pressure which expelled the blood from the pial arterioles of the exposed brain surface. Different concentrations of 6 contrast media and of NaCl were perfused, each concentration being tested in 4 to 6 animals.

The animal was killed 30 to 45 minutes after carotid perfusion. The chest was opened, the right atrium cut, and 200 ml of 0.9% NaCl followed by 400 ml of 10% formaldehyde solution was perfused through the left ventricle when the descending aorta was clamped. The brain then was removed and observed and photographed for staining and distribution of extravasated Evans blue dye both on the surface and after sectioning. Kodachrome slides were examined later without knowing which agent was perfused, and barrier damage was classified in four groups as follows: (0) No observable extravasation of dye; (+) light extravasation in local region, usually at the left temporal lobe; (++) light and diffuse extravasation over greater part of left hemispherical cortex; (+++) diffuse dye extravasation over left hemisphere with superimposed dark blue regions.

Occasionally dye extravasated in the right rather than left hemisphere possibly because of variations in vascular architecture or reactivity (JEPPSON & OLIN 1970). We did not distinguish between left and right-sided damage in our classification.

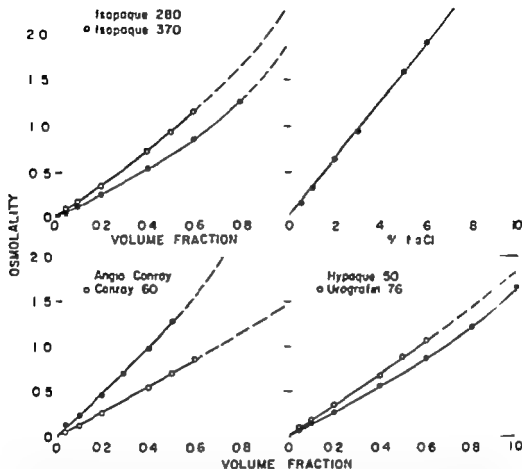


Fig. 1. Relation of solution osmolality to volume fraction of contrast medium and 1 percent NaCl (g/100 ml). The abscissa is $V_m/(V_m + V_w)$ where V_m = volume of contrast medium, V_w denotes water. The points are experimentally determined osmolalities. Osmolalities of high volume fractions and of diluted media are not given because either freezing did not occur at the normal supercool temperature or measurements were not reproducible. Dashed lines represent extrapolated osmolalities in these regions.

Solutions: The 11 contrast media used are listed in the Table together with their generic names and salt contents when available. They had 3 different anions and different cation contents. Angio-Conray and Conray 60 are manufactured by Mallinckrodt Chemical Works (St. Louis, Missouri). Urografin 76 by Schering A. G. (Berlin, West Germany). Hypaque 50, Isopaque 370 and Isopaque 280 by Sterling Winthrop (New York, N.Y.). Conray 60, Hypaque 50, Urografin 76 and Isopaque 280 are used for carotid angiography, while Angio-Conray and Isopaque 370 are not.

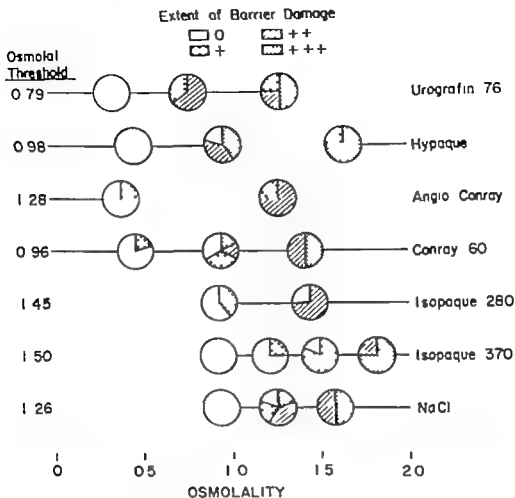


Fig 2 Blood brain barrier damage at different osmolalities of 6 contrast media and NaCl. Barrier effects at different osmolalities of given agent are presented on horizontal line. The center of circle denotes the osmolality of the solution which was tested by internal carotid perfusion. Each circle is divided proportionately to the fraction of animals in which given grade of barrier break down was produced.

Solutions of given volume fractions of contrast media (Table) were injected into the internal carotid artery to test barrier opening ($\text{Volume fraction} = \frac{V_m}{V_m + V_w}$ where $v = \text{volume in}$ denotes medium and $w = \text{water}$). Threshold and extent of damage were examined for each solution and related to solution osmolality. Threshold for BBB opening is defined as the lowest test osmolality which produced some damage (+ to +++) in at least 50 per cent of the animals.

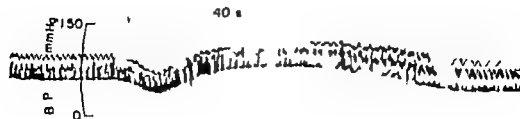


Fig. 3. Blood pressure response to intralipid perfusion (0.8 ml) of Urografin 76. The temperature of the perfused animal was 37°C.

Osmolalities were measured by freezing point depression with a Precision Systems Osmometer (Natick, Massachusetts) and were related to volume fractions of the media (Fig. 1). For undiluted or slightly diluted media freezing either did not take place at the normal supercool point or measurements were not reproducibly possible because solute and solvent separated out simultaneously (BORDALEY *et al.*, 1970). For more dilute solutions osmolality was roughly linear with volume fraction. Osmolalities of the concentrated solutions were estimated by extrapolation and agreed with osmolalities as found by Hill's method to within about 10 per cent (BORDALEY *et al.*, 1970; personal communication). Osmolalities corresponding to given volume fractions are listed in the Table.

Results

Fig. 2 presents observations on barner breakdown by the 6 contrast media and NaCl. Barner openings at different osmolalities of each medium are presented on a single horizontal line. The center of a circle denotes the osmolality of the solution which was tested; the corresponding volume fraction can be found from Fig. 1 or the Table.

Each circle is divided proportionately to the fraction of animals in which a given grade of barner breakdown was produced. For instance, 1.9 osmolal Urografin 76 produced +++ damage in 1/3 of the animals tested, ++ damage in 1/3 and + damage in 1/3. Four to 6 animals were tested at any given osmolality of an agent.

The proportion of animals in which ++ and +++ damage were produced increased with increasing osmolality for each agent. Threshold or the lowest osmolality which produced + to +++ damage in at least 50 per cent of the animals tested is given on the left hand side of each horizontal line. The mean threshold for the 6 contrast media is 1.16 ± 0.27 SD osmolal and does not differ significantly ($p > 0.05$) from the NaCl threshold of 1.26 osmolal.

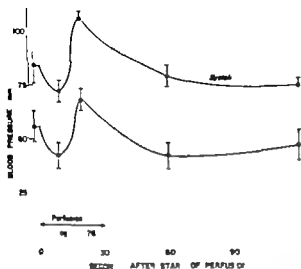


Fig. 4. Mean blood pressure changes following internal carotid perfusion of 0.8 osmolal and 1.3 osmolal solutions of Urografin 76. The baseline bars represent means \pm SD for 7 animals. The points at 0 and 30 seconds represent mean maxima and minima in systolic and diastolic pressures while those at 1 and 2 minutes are mean pressure levels. The corresponding SD are calculated from differences with each animal between observed and baseline (zero time) pressures.

The range of thresholds in Fig. 2 encompasses those of the media of the Diodrast group tested by BROVIAN & OLSSON (1949) and BASSETT *et al.* (1953). Umbradil Forte (Diethanolamine salt of 3,5-diiodo-4-pyridone N-acetic acid + Diethylamine) was shown to break down the BBB under similar experimental conditions at 1.3 osmolal. Diodon 35 γ (Diethanolamine salt of diiodo-pyridone N-acetic acid) opened the barrier at 0.8 osmolal and Diodrast 35 γ (Diethanolamine salt of 3,5-diiodo-4-pyridone N-acetic acid) did so at 1.0 osmolal (cf. RAPOPORT 1973a).

Cardiovascular effects. The contrast media may affect profoundly the cardiovascular system (ALMEY 1971). TORNELL (1968) used the hypotension and bradycardia produced by internal carotid perfusion as an index of neurotoxicity but HILAL (1966) and JEPPESSON & OLIN (1970) concluded that convulsions and blood brain barrier damage were independent of cardiovascular effects.

We also found that perfusion of contrast media and NaCl usually produced an initial fall in blood pressure which reached a minimum 10 seconds after the start of perfusion followed by a secondary rise in pressure that reached a maximum at about 20 seconds and lasted for the duration of perfusion. Bradycardia usually was associated with the pressure changes.

Fig. 3 is an example of the blood pressure response to Urografin 76 perfusion but without bradycardia and Fig. 4 summarizes the responses in 7 animals to 0.8 and 1.3 osmolal Urografin 76 perfusion. At 1 and 2 minutes after perfusion starts blood pressure returns to close to its initial value.

The hypertensive responses to media injected at threshold and at the next higher osmolality (Fig. 2) are ranked as follows for 4 agents adequately examined: $\text{NaCl} = \text{Isopaque 370} > \text{Urografin 76} > \text{Conray 60}$. Conray 60 did not give a statistically significant hypertensive response. Neither the hypertensive nor hypotensive response to perfusion was correlated with threshold for BBB breakdown (cf Fig. 2).

Discussion

In view of the many factors that could affect retention and delivery of contrast media to the cerebral vessels it is not surprising that the range of threshold osmolalities for barrier breakdown is between 0.8 and 1.5 osmolal with a SD of 0.26 and that the grade of barrier opening at threshold is variable (Fig. 2). The end point of Evans blue staining moreover is a gross indicator of BBB opening and probably occurs at higher osmolalities than necessary for smaller tracers (RAPOPORT 1973a).

The close grouping of the thresholds of the 6 contrast media in the Table suggests that they act in the main as a function of number of solute molecules or their osmolality and that their different chemical and electrolyte compositions modify but do not determine strongly the threshold for BBB breakdown. The thresholds of the three media previously tested—Umbradil Forte, Diodrast and Diodrast—and of NaCl belong to the same population as do the thresholds in Fig. 2, further supporting the hypothesis that the media as a whole act on the barrier at approximately the same osmolality.

Osmotic opening of the blood brain barrier should depend on solution osmolality and be independent of chemical specificity and should be reversible (RAPOPORT 1971, 1973a). The approximately equ-osmolal thresholds of the 6 contrast media and of NaCl support the suggestion that they open the barrier osmotically. Furthermore the reversible opening by the media and by NaCl also agrees with the osmotic hypothesis (BROMAN & OLSSON 1948; FLODMARK & STEINWALL 1963; STRICKLER et coll. 1964; RAPOPORT et coll. 1972).

The tight junctions between the cerebrovascular endothelial cells are opened by the osmotic action of urea and probably of other concentrated solutions (RAPOPORT et coll. 1972, 1973). On the basis of the equ-osmolal actions of the contrast media on the BBB we suggest that these agents also open the barrier by opening the tight junctions probably by shrinking endothelial cells. This suggestion must be tested by electron microscopy.

More investigations should be done also on the time course of reversibility as a function of concentration, chemical composition and perfusion time. In the rabbit, the barrier closes within 30 minutes after being opened by 2 molar urea and following Diodrast 35% perfusion it closes within 2 hours (RAPOPORT

1973 a BROMAN & OLSSON 1948) EEG changes following brain entry of contrast media may last longer than 2 hours because of slow excretion from the brain extracellular space (FLODMARK & STEINWALL 1963 CSERER 1971)

Knowing reversibility time is important for the clinic because neurologic sequelae follow more often the second rather than the first perfusion of a contrast medium when the second is given within 15 minutes of the first (HILAL 1966) Although convulsions are not produced by hypertonic NaCl solution alone an initial hypertonic NaCl perfusion increases the incidence of convulsions to later perfusion of contrast media, suggesting that the hypertonic NaCl has opened the barrier (HILAL 1970)

Osmolality appears to be a major regulator of the extent and distribution of BBB breakdown, but the chemical nature of the contrast medium may play a part The anions of contrast media have specific effects on 32 P uptake by brain and on microcirculation and Na⁺ Ca²⁺ and meglumine contents also may affect BBB opening (GONSETTE & ANDRE BALISAVAN 1969 MARGOLIS & YERASIMIDES 1966 ALMER 1971) From the present data and those of JEPSSON & OLIN (1970) and HILAL (1966) experimental barrier opening does not appear to be affected strongly by the systemic cardiovascular responses to intracarotid perfusion unless marked hypotension is produced

Barrier opening and neurotoxicity are not equivalent Media with high Na content do not open the barrier at lower osmolalities than media with the corresponding anions but lower Na (Fig 2) although the latter are less neurotoxic clinically (HILAL 1970 ALMER 1971)

Permanent ligation of the common carotid artery in the monkey performed usually in investigating the effect of agents on the barrier using internal carotid perfusion (STEINWALL 1958) will produce often ischemic necrosis of the perfused hemisphere (RAPOPORT et coll 1972) However osmotic barrier opening by 2 molar urea or lactamide can be produced without apparent long term neuronal damage if perfusion is through the lingual artery and if the common and external carotid arteries are clamped only for the period of perfusion (RAPOPORT 1973 b RAPOPORT & THOMPSON 1973)

Neurotoxicity therefore is related to the specific effect of the medium on neuronal function once it enters the brain When the barrier is intact, entry into the brain of drugs and electrolytes that exist in dissociated (ionic) and associated forms is regulated mainly by the concentration of the associated form at blood pH, and by the pH difference between blood and cerebrospinal fluid RALL et coll 1959) The insoluble contrast media are mainly dissociated at physiologic pH The ionic contrast media, iotrizoate, metrizoate, iohalamate and iodopyracet range from 3.1 to 3.5 in methanol water (NICKEL personal communication)

REFERENCES

- ALVÉN T. Toxicity of radiocontrast media. *J. Radiocontrast agents* Vol. 1. Edited by P. K. Knöfel. Pergamon Press, Oxford, 1971.
- BAMETT R. C., ROYCE J. S., CHERRY G. R. and GRIZZITT C. The effect of contrast media on the blood brain barrier. *J. Neurology*, 10 (1953) 38.
- BORDALEN B. E., WANG H. and HOLTERMAN. II. Osmotic properties of some contrast media. *Invert Radiol* 5 (1970) 559.
- BRIGHTMAN M. W., HORI M., RAPOPORT S. I., REISE T. E. and WESTERGAARD I. Osmotic opening of tight junctions in cerebral endothelium. *J. comp. Neurol.* (in press).
- BRODMAN T. and OLSSON O. The tolerance of cerebral blood vessels to contrast medium of the diatrizoate group. An experimental study of the effect on the blood brain barrier. *Acta radiol* 30 (1948) 3-6.
- — Experimental study of contrast media for cerebral angiography with reference to possible injurious effects on the cerebral blood vessels. *Acta radiol* 31 (1949) 3-1.
- CHERRY H. F. Physiology of the choroid plexus. *Physiol. Rev.* 51 (1971) 273.
- FLOODMARK S. and STERNWALL O. Reversible blood brain barrier alteration induced by certain organic acids and indicated by means of EEG and d. tests. *Acta physiol. scand* 58 (1963) 568.
- FRIEDMAN F. II and JOHNSON J. A. Equilibrium and kinetic properties of the Eosin blue albumin system. *Amer. J. Physiol* 216 (1969) 675.
- GOSSETTE R. et ANDRÉ BALBAZAT G. Étude expérimentale en l'homme de la tolérance des capillaires cérébraux pour une nouvelle substance de contraste (sels de l'acide iotalamique). *Acta radiol. Diagnosis* 8 (1969) 535.
- HARRINGTON G., MICHU C. L., MUI P. R., RUSSELL M. A. and OPPENHEIMER M. J. Blood brain barrier changes associated with unilateral cerebral angiography. *Invert Radiol* 1 (1966) 431.
- HILL S. K. Hemodynamic responses in the cerebral vessels to angiographic contrast media. *Acta radiol. Diagnosis* 5 (1966) 211.
- Trends in preparation of new angiographic contrast media with special emphasis on polymeric derivatives. *Invert Radiol* 5 (1970) 458.
- JERSSON P. G. and OLIN T. Neurotoxicity of roentgen contrast media. Study of the blood brain barrier in the rabbit following selective injection of contrast media into the internal carotid artery. *Acta radiol. Diagnosis* 10 (1970) 17.
- JARROLD M. J. The ultrastructural basis of transcapillary exchanges. *J. gen. Physiol* 5 (1968) 644.
- LANGE K. F., JAMES G., EBERFELD M., MORDE T. J. and VAMONTE M. Cerebrovascular permeability of water soluble contrast material Hypaque (sodium diatrizoate). Experimental study in dogs. *Invert Radiol* 5 (1970) 79.
- MARGOLIS G. and YERASIMIDIS T. G. Vasopressor potentiation of neurotoxicity in experimental aortography. Implications regarding pathogenesis of contrast media injury. *Acta radiol. Diagnosis* 5 (1966) 388.
- MCCLELLAN B. L. and BARNES J. A. Cerebrospinal fluid transfer of contrast material at urography. *Amer. J. Roentol* 113 (1971) 427.
- NICKEL A. R. Personal communication 1972.
- OLDENDORF W. H. Blood brain barrier permeability to lactate. *Europ. neurol* 6 (1971/72) 49.
- RALL D. I., STARR J. and ZIMMERMAN C. G. Distribution of drugs between blood and cerebrospinal fluid. C. methodology and effect of pH gradients. *J. Pharmacol. exp. Ther.* 125 (1959) 18.

- RAPHOORT S. I. Effect of concentrated solution on blood brain barrier. *Amer J Physiol* 219 (1970) 770
- The cortical acidic response to intravenous NaHCO_3 and the nature of blood brain barrier damage. *Int J Neurosci* 1971 1
 - (a) Evidence for reversible opening of the blood brain barrier by osmotic shrinkage of the cerebrovascular endothelium and opening of the tight junctions. Relation to carotid stenography. / Symposium on serial cerebral angiography. Association of University Radiologists April 23-26 1971 Glen Cove Long Island New York C. V. Mosby Company St. Louis 1973 (in press)
 - (b) Target organ modulation in pharmacology: reversible osmotic opening of the blood brain barrier by opening tight junctions. / Pharmacology and pharmacokinetics. Problems and perspectives. Society International Center Proceedings No. 70 Edited by T. Georeff, R. L. Deitsch and J. Condliff. Plenum Publishing Company New York 1973 (in press)
- BACHMAN D. S. and THOMPSON H. A. Chronic effect of osmotic opening of the blood brain barrier in the monkey. *Science* 176 (1972) 143
- BACHMAN D. S. and THOMPSON H. A. Reversible osmotic opening of the blood brain barrier (BBB) by opening of tight junctions of cerebrovascular endothelium. Abstracts 17th Annual Meeting Biophysical Society 13 (1973) 230a
- HORI M. and KLEIN J. Testing of hypothesis for osmotic opening of the blood brain barrier. *Amer J Physiol* 225 (1973) 123
 - and LEVITAN H. Dependence of neurotoxicity of X-ray contrast media on lipid solubility. Abstracts 17th Annual Meeting Amer Soc Neuroradiology April 1973 p. 4
 - and THOMPSON H. A. Osmotic opening of the blood brain barrier (BBB) in the monkey without associated neurological deficits. *Science* 180 (1973) 971
- REZER T. S. and KARNOVSKY M. J. Fine structural localization of a blood brain barrier to exogenous peroxidase. *J cell Biol* 31 (1967) 707
- ROSENTHAL L. AVONIA WOLO S. and STRATHORN J. Observations on the effect of contrast material on normal and abnormal brain tissue using radioisotopes. *Radiology* 99 (1969) 1467
- STERNHALL O. An improved technique for testing the effect of contrast media and other substances on the blood brain barrier. *Acta radiol* 49 (1958) 281
- STEFANICH G. RALL D. I. and GASKINS J. R. Distribution of thiocyanate between plasma and cerebrospinal fluid. *Amer J Physiol* 206 (1964) 51
- TORRELL G. Bradycardial reactions in cerebral angiography induced by sodium and (b) glucuronate rothalamat (Contray). Comparison with Urografin in controlled study in man. *Acta radiol. Diagnosis* 7 (1968) 489

OBSERVATION OF THE CERVICAL SEGMENT OF THE SPINAL CANAL BY AN EXTENSION DEVICE

AKOS KOVACS

The cord is suspended elastically in the spinal canal so that the effect of movement is considerably decreased. There are two components of any movement: one being the result of traction of the cord while the spine is bowed and the other its inherent displacement composed again of two types: viz. one being the result of transmitted arterial pulsation and the other changes in the pressure of the fluid (KOBLENDAHL 1970). Thickening or calcification of the dura may inhibit these movements by interfering with the blood supply of the cord; this is dependent on the integrity of branches of the anterior spinal artery which enters the cord through septum-like structures between the arachnoidea and dura. The dura mater of the spine consists of internal and external laminae separated from each other below the epistropheus by a space filled with a venous plexus, lymphatic vessels and adipose tissue.

The posterior longitudinal ligament that extends along the spinal canal is loosely attached to the external lamina of the dura; on the other hand it adheres firmly to the wall of the intervertebral foramina. According to RAU (1972) thickening of the dura, arachnoid adhesions and cysts frequently occur with chronic mechanical irritation. Smaller or larger calcified areas are often

Submitted for publication: 1 October 1972



Fig. 1. Thickening of the posterior longitudinal ligament and narrowing of the vertebral canal. Lesions of the spinal cord.

observed in the dura at laminectomy. GATZLER (1971) however, surveyed 200 healthy young individuals at roentgen examination and failed to detect calcification in the posterior longitudinal ligament. BOJSEY (1954) and later RAY (1972) pointed to the relatively great variability in the sagittal diameter of the spinal canal 12 to 14 mm. The cervical segment of the cord lying in a relatively narrow part of the spinal canal is easily exposed to mechanical irritation from thickening of the dura or ligaments and from disc protrusions (Fig. 1).

Examination of the posterior margins of the vertebrae seems thus to be important; unfortunately conventional lateral roentgenogram of the cervical spine are not suitable for this purpose as the articular processes mask this area. Two variations are encountered in the cervical spinal column. If a lower vertebra is anteposed the upper end of the articular process hides the postero-inferior edge of the vertebra above it (Fig. 3); if an upper vertebra is anteposed the process of the lower vertebra does not interfere with this part of the upper vertebra (Fig. 2).

Apart from normal anatomic variations three further possibilities contribute to the difficulties in depicting the posterior edge of the vertebrae in the film.

Congenital malformation (deformed articular process) The articular surfaces of the adjacent vertebrae form two parallel oblique planes. The block enclosed by these planes has normally a rhomboid appearance in a lateral view. The upper articular surface may however have a more oblique (almost vertical) position. The block then loses its rhomboid appearance and approaches the form of a triangle. The upper vertebra consequently will slip along the articular surface of the upper process posteriorly and downward and the posterior lower edge of



Fig 2

Fig 2 The deformed articular process and its projection in relation to the vertebral body

Fig 3 The upper end of the articular process without and with traction (top and middle). The transverse block obscures the posteroinferior edge of the upper vertebra



Fig 3

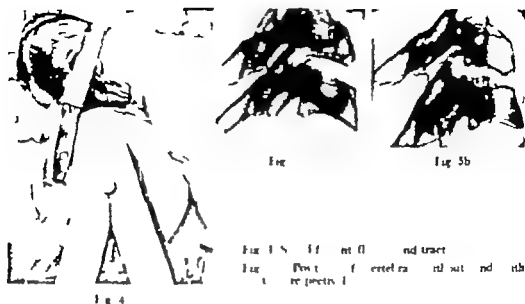
the vertebra will be obscured in the film (Fig 2). If there are several such deformed blocks the shape of the whole spinal column will be altered the cervical lordosis, eventually also the dorsal kyphosis being augmented.

Increased lordosis without such deformity

Arthrosis of the small joints The broadened protruding superior articular process and osteophytes cover the posteroinferior edge of the vertebra.

In uncomplicated cases the functional roentgenogram in anteflexion recommended by JUNGHAUS (1952) is usually satisfactory for the check of the posterior portion of the cervical vertebra and the anterior wall of the spinal canal while in other cases the addition of extension to anteflexion may be useful.

Anteflexion and traction at the same time may be performed with a simple stand and rotating disc provided with a belt for fixation of the head and a cushion for the chin and forehead. The patient pushes his fixed head forward by means of the two handles (Fig. 4) until he feels that further traction would cause pain. By allowing the arms and shoulders to hang the transverse dimension of the lower cervical part becomes narrower. Extension for a few minutes causes the



vertebrae to move slowly apart (Fig. 5b). If care be taken that the central ray be parallel to the frontal plane, the right and left articular processes will be projected upon each other and no bony part will cause masking. By this procedure ossified ligament and cartilage protruding into the spinal canal may be demonstrated if they contain at least some deposited calcium. Koeniggenograms taken after this procedure will produce a clear representation of the posterior edge of the vertebrae. The films of the neck will be rich in detail with the flexible cassette of Schinz. Sagittal tomograms were also obtained in all positive cases. For obvious reasons the presence of an odontoid bone or aplasia of the dens have to be excluded before application of this traction technique.

HENSON (1957) has demonstrated in healthy, curarized and anaesthetized individuals that C2 to C6 are considerably displaced from each other during traction for several minutes and the articular surface of the small joints enclose a space that is 1 to 2 mm broader than without traction. The women of the Anan Padoung people extend their neck to 30 to 50 cm by a spiral device made of copper, a procedure that is started at the age of 10 to 12 years. When the child becomes adult her vertebrae have formed from each other by several centimeters. This abnormal extension of the wire coil producing this effect seem to cause no untoward symptoms.

It is absolutely necessary to carry out the proposed procedure with almost geometric accuracy. If for example the sagittal plane of the patient is not



Fig 6 Calcified ligament not visible on a) straight lateral view but on b) slightly oblique view



Fig 7 Case 1 Ligament calcification behind a fractured vertebra



Fig 8 Case 2 Calcified longitudinal ligament



Fig 9 Case 3 Ligament calcifications between C3 and C6



Fig 10 Case 4 Ligament calcification behind a fractured vertebra

parallel with the film projection distortion may occur. Thus the cortical contour of the uncinate process may reach the edge of the vertebra lying above it and may be confused with a calcified longitudinal ligament. A calcified ligament is, however, not invariably demonstrated even with this technique for if the calcified part of the ligament lies in a corresponding concavity of the spinal column it can be depicted only by turning the neck by 10 to 15° (Fig. 6) or by tomography.

It is often impossible in patients with short and relatively stiff necks to reveal the posterior contour of the disc or the vertebral edge. Nevertheless the method described may also prove useful since comparison of the conventional films taken with and without extension may yield important information. Structures in the area of the spinal canal may consist of the posterior edge of the vertebra, the longitudinal ligament or the dura or circumscribed sclerosis of the articular process. If, however, such structure moves upwards with the upper vertebra in extension, the conclusion has to be drawn that it does not represent a calcified ligament or cartilage but belongs to the bony structures of the upper vertebra.

Calcification of the posterior longitudinal ligament of the spine. It is common knowledge that under certain circumstances mechanical or chemical irritation may result in local calcification of tissues. Deposition of calcium is particularly common in periarthicular tissues often followed by complete ankylosis. This reaction obviously constitutes protection of abnormally weak joint cartilage or intervertebral disc by restricting the movements. Radiographic examination of traumatized limbs often reveals calcification of the soft tissues near the joints. POLCAR (1929) in referring to the ossification of the spinal ligaments distinguished calcification of the ligamentum flavum and retrocorporal calcification. SCHMORL & JUNGHANS (1952) observed retrocorporal calcification only in one of 10 000 cases examined post mortem but more frequently calcification of the ligamentum flavum often associated with diseases causing rigidity of the spine (spondylarthrosis senile, kyphoscoliosis). These changes would appear to occur much more frequently and can usually be demonstrated by careful roentgen examination of the cervical part of the spine.

OHJI & ARAI (1963) have attributed compression of the cervical cord in 18 Japanese patients with myelopathy to encroachment by a calcified posterior ligament. Subsequently, MINAOI & GROVNER (1969) as well as HIRAMATSU & NOBECCHI (1971) have suggested that Japanese subjects tend to have more calcification in the ligaments than do Caucasians.

In the course of the past 11 years a total of 8 700 patients of Caucasian origin has been subjected to roentgen examination of the cervical spine because of cervicobrachial symptoms. Of these 101 had calcification of the posterior longi-



Fig 11 Dural calcifications posteriorly and anteriorly

tudinal ligament and disc degeneration combined with myelopathy was evident in 8 patients. 14 had suffered trauma.

Case reports

Case 1 Male aged 24. One year after a compression fracture the posterior longitudinal ligament behind the fractured vertebra was calcified (Fig 7).

Case 2 Female, aged 38, had fallen on her head 5 years previously from a tractor. Complained of headache. Calcification of the posterior longitudinal ligament between C3 and C4 (Fig 8).

Case 3 Female, aged 29, complained of cracks in her neck when taking her child weighing 20 kg on her neck. Extensive calcification of the longitudinal posterior ligament between C3 and C5 (Fig 9).

Case 4 Female, aged 37, complained of frequent headache. Calcification of the posterior longitudinal ligament between C2 and C4 (Fig 10).

Case 5 Female, aged 35, complained of headache. Calcification of the dura anteriorly as well as posteriorly C3—C6.

Case 6 Male, aged 47, had been hit by a stone slide in a mine 26 years before without bone lesion. He presented with pain in the neck and headache. Radiography revealed similar ossification of the dura (Fig 11).

Discogenic lesions of the spinal cord were first reported in 1940 by STODOLSKY, later by BUCY et coll (1948), FRYKHOLM (1951), BRAIN (1954), LIVERSIDGE et coll (1963), CLARKE (1955), MACDONALD (1955), O'CONNELL (1955), SEGERBERGER (1956) and BALTAVARY (1956). CLOWARD (1958) distinguished three groups: (1) Acute rupture of the disc; (2) Slowly developing degenera-

tion of a disc. Symptoms and signs develop slowly, neuritides and pareses are occasionally followed by partial paralysis. 3. Protrusion or herniation of a disc into the spinal canal. Symptoms and signs are similar to those of a spinal tumour (Group 2), most frequently observed.

The radiologic diagnosis is accomplished by myelography which, however, often fails to demonstrate the filling defect caused by disc herniation especially if it is located laterally. Discography, a more direct method, has also been used.

Neither myelography nor discography is indifferent for the patient; we have tried to make maximum use of the extension technique. In the vast majority of cases the ligament calcifications and protrusion of the disc could be demonstrated. Our observations are in agreement with those of MIXTER *et al.* (coll. 1955) who compared the myelographic changes with those seen in conventional film. They found no correlation between the osteophytes on the anterior and lateral edges of the vertebrae and the lesions demonstrated by myelography. On the other hand, an osteophyte on the posterior edge indicated the site of compression in 31 of 33 cases. Similar osteophytes of the posterior edge above or below the protrusion or herniation were often encountered also in our material.

Bad results of surgery are often encountered partly due to the fact that operation was performed too late when irreparable lesions of nerve structures already had appeared. The lateral film taken during anteflexion and traction combined with sagittal tomography can be carried out at a time when symptoms and signs are still scanty, thus facilitating an early diagnosis.

SUMMARY

For the diagnosis of cervical ligament and dura thickenings as well as of chronic myelopathies, myelography is the generally adopted method. In early cases patients are willing to give their consent to the examination, but in later cases the results of operation are rarely satisfactory. A special device exerting traction on the head and bringing the neck in anteflexion, the number of cases diagnosed on conventional roentgenograms or possibly supplemented by sagittal tomography can be increased whereby myelography will in many cases become superfluous.

ZUSAMMENFASSUNG

Zur Diagnose der zervikalen Ligament- und Dura Verdickungen sowie bei Bandscheiben Myelopathien ist die Myelographie eine allgemein akzeptierte Method. In frühen Fällen sind die Patienten nicht gewillt ihre Zustimmung zu dieser Untersuchung zu geben, während in späten Fällen das Ergebnis einer Operation selten zufriedenstellend ist. Durch eine spezielle Anordnung mit der der Kopf einem Zug unterzogen und der Hals in Anteflexion gebracht wird, kann die Zahl der diagnostizierten Fällen mit konventioneller Röntgentechnik möglicherweise ergänzt durch sagittale Tomographie gesteigert werden, wodurch eine Myelographie in vielen Fällen überflüssig wird.

RÉSUMÉ

La myélographie est une méthode généralement adoptée pour le diagnostic des épaulements des ligaments cervicaux et de la dure-mère ainsi que pour les myélopathies d'origine discal. Dans les cas début les malades n'ont pu donner leur consentement à cet examen alors qu'à stade tardif le résultat de l'opération est rarement satisfaisant. Un dispositif spécial exerçant une traction sur la tête et antena à la cou en flexion antérieure permet d'augmenter le nombre des cas diagnostiqués sur les radiographies simples ou éventuellement complétées par tomographie sagittale ce qui rendra la myélographie superflue dans de nombreux cas.

REFERENCES

- BALTSARYS L. Akut kompression des Halsmarkes durch Bandscheibenprolaps. *Nervenzentr.* 27 (1956) 176.
- BOGREN E. The cervical spinal canal in intraspinal expansion, processes. *Acta radiol.* 42 (1954) 101.
- BRADY R. Spondylitis. The known and the unknown. *Rheumatism* 13 (1954) 1.
- BLOY P., HERMANSBURGER R. and OZGIBULL H. Compression of cervical spinal cord. *J. Neurosurg.* 5 (1948) 471.
- CLARKE E. Cervical myelopathy. *Lancet* 22 (1955) 171.
- CLOWARD B. Cervical disk protrusions. *Amer. J. Roentgenol.* 79 (1958) 4.
- FRYBOLM R. Cervical nerve root compression. *Acta chirurgica* (1951) Suppl. No. 160.
- GAZDAR G. Inaugural dissertation. Hungarian Academy of Sciences 1971.
- HIDAMATYU Y. and NOSHORI T. Calcification of the posterior longitudinal ligament. *Radiology* 100 (1971) 507.
- HENNING J. Die Halswirbelsäule in Langzeit. *Fortschr. Röntgenstr.* 87 (1957) 726.
- J. VON HANAU H. Die funktionelle Röntgenuntersuchung der Halswirbelsäule. *Fortschr. Röntgenstr.* 76 (1952) 59.
- KOVACS Á. Herniated disks and vertebral ligaments. *Acta radiol.* 32 (1949) 287.
- KULLENDAM H. Analyse der Biomechanik der Halswirbelsäule I. Wirbelsäule und Nervensystem. S. 16. Herausgegeben von E. Trosdorf und H. Stender. Georg Thieme Verlag Stuttgart 1970.
- Nephralgia subatlantica Arac Cervicalis. *Fortschr. Röntgenstr.* 85 (1956) 142.
- LAKSEMAN H. Hintere Langzeit röntgenuntersuchung kombiniert mit Wirbelkörperverletzungen. *Fortschr. Röntgenstr.* 116 (1972) 834.
- LEVINSKY L. A., HUTCHINSON E. C. and LEON J. B. Cervical spondylitis simulating motor neuron disease. *Lancet* 26 (1963) 632.
- LOOZE W. Thoracic disk prolapse. *J. Neurol. Neurosurg.* 15 (1955) 228.
- MACDONALD H. V. Anterior cervical cord compression. *Proc. May Clin. Soc.* (1955) 1.
- MINAGI H. and GROVNER A. F. Calcifications of the posterior longitudinal ligament. *Amer. J. Roentgenol.* 105 (1969) 365.
- MIRREATH F., CHAMBERLAIN W. F., SCOTT M. and WYNN H. T. Cervical spondylitis. *Amer. J. Roentgenol.* 74 (1955) 1.
- O'CONNELL J. E. Involvement of the spinal cord by disk protrusions. *Brit. J. Surg.* 43 (1955) 179.
- OGI Y. and AKIYAMA H. Surgical treatment of cervical myelopathy. *J. East Asian Orthop.* A 2 (1965) 103.

- LOTCAR I Über funktionelle Wirbelverkalke g Fortsch Röntgenstr III (1979) 21
- RAU H Röntgenologische Fragenstellungen am Nervenbild aus der Sicht des Neurologen
Radiolog 12 (1972) 58
- ROAF H Craniocervical women J Bone Jt Surg 43 (1960) 114
- SCHWAB C und JUNODHAS H Die gesunde und krank Wirbelsäule Georg Thieme Verlag Stuttgart 1952
- SPENGLER E L Spinal cord in cement Age Surg 2 (1956) 227
- STEVY H CARBIA J C and SYRSTWON N Histochemical studies in calcergy J Histochem 12 (1964) 563
- STOCKER B Dystrogen lesion of the spinal cord Arch Surg (Chic) 40 (1940) 417

PHLEBOGRAPHY IN THE KLIPPEL-TRENAUNAY SYNDROME

M LEA THOMAS and G B MACFIE

KLIPPEL & TRENAUNAY (1900) described a clinical syndrome consisting of a naevus confined to one lower limb varicose veins on the same side dating from birth or infancy and hypertrophy of bone and soft tissues of the affected limb. Their description made no mention of symptoms or signs suggestive of an arteriovenous fistula. Since then there have been a large number of reports of a similar syndrome (PARKES WEBER 1907 NAZARRO 1954 SERVILLE 1964 LINDENAUER 1965 1971 LANGERON & VERCAUTEREN 1970) to name only a few. Other authors include in the term Klippel Trenaunay syndrome patients with arteriovenous fistula (PARKES WEBER 1918 1949 HARRIS & WRIGHT 1929 BLUMGART & ERNSTEIN 1932 CULLITY 1951 GALICER & NERIO CHICOTE 1956 BOUVRAIN & BOURHOUMIEUX 1957 DESMONS & PELZER 1957 COTTO & SYKES 1969). Generally however the view is now accepted that the term Klippel Trenaunay syndrome should be reserved for a purely venous dysplasia (MALAN & PLOLONISI 1964 LINDENAUER 1965 1971). Such a limitation in terminology is of practical value as the management and the prognosis are affected by the presence of arteriovenous shunting.



FIG. 1. Case 11. Left leg, a varicose vein, lateral view, and right leg, bony hypertrophy.

SERVELLE (1945) was the first to describe the use of phlebography to demonstrate the venous abnormality in Klippel-Trenaunay syndrome. Since then it has become widely practiced (MEYERS & JONES 1955; IECHE 1957; SERVELLE 1957; FOSTER & HERTLEY 1959; MARTORIEL & MONSIEU 1962; ODA et al. 1962; LINDENAUER 1963; LEA THOMAS & ANDREWS 1971).

The phlebographic findings in 14 patients with the Klippel-Trenaunay syndrome are described in this report. The clinical features and other radiographic findings are briefly recorded.

Material. Fourteen patients with the Klippel-Trenaunay syndrome were investigated by phlebography. Six patients were male and eight female. All patients had a cutaneous naevus noted at birth and nine of these presented at this time, one presented at 2, one at 5, one at 11 and two at 17 years.

All the patients had varicose veins. In eight patients there was bony hypertrophy and in ten there was thickening of the soft tissues (Fig. 1). Eight patients had oedema of the legs. Cutaneous naevi were present on the right leg in eight patients, on the left in five and in one patient the naevus was bilateral though



Fig 2



Fig 3a



Fig 3b

Fig 2 Case 1. Peripheral phlebogram of right leg. Deep venous system of the thigh absent.

Fig 3 Case 6. a) Peripheral phlebogram of right leg. There are large lateral venous trunks connecting with the profunda system. b) Direct injection phlebogram. Thoraco-lateral trunk is more clearly demonstrated.

greater on the right leg than on the left. Arteriography was carried out in six patients and conventional films of the affected limb taken in four. The findings are summarised in Table 1.

In some patients no treatment was indicated. In others the treatment consisted of conservative measures only: tying of varicose veins, ligation of venous trunks, relief of obstruction and excision of subcutaneous fat. The type of treatment and its results are shown in Table 2.

Phlebography. The phlebographic techniques used have been described in detail elsewhere. In most instances phlebography by injection of foot veins was

Table 1

Clinical features and phlebographic findings

Case and sex	Age at presentation	Affected leg	Iliaic hypertrophy	Soft tissue hypertrophy	Oedema	Other symptoms	Conventional films
1 M	17	R	-	-	+	1 in	-
2 F	17	R	-	+	-	-	-
3 F	5	R	+	+	+	Cellulitis	-
4 F	Birth	L	-	-	-	-	-
5 M	Birth	R	+	+	-	-	1 cm length not
6 F	Birth	R	-	-	+	1 in	-
7 M	Birth	R	+	+	-	Bleeding	-
8 F	2	L	-	+	+	Pain	Pain
9 M	Birth	L	+	+	+	-	1 cm 1 gtl not
10 F	11	L	-	+	+	-	-
11 M	Birth	Both	+	-	-	-	-
12 F	Birth	L	+	-	-	Thrombophlebitis	Phlebolith
13 M	Birth	R	+	+	+	Haematoma from bladder angioma	-
14 F	Birth	R	+	-	-	-	-

Tabl 1 (cont)

Arteriography	Type of phlebogram	Findings
-	Peripheral phlebogram	Absent calf and femoral veins lateral venous trunk with perforating veins joining profunda vein venous angiooma of foot
+	Peripheral phlebogram	Distended superficial veins normal deep veins
+	Peripheral phlebogram direct injection	Absent femoral vein incompetent perforating veins of calf lateral venous trunk
-	Peripheral phlebogram	Absent deep veins of calf and thigh
+	Peripheral phlebogram	Normal deep veins incompetent perforating veins of calf
-	Peripheral phlebogram direct injection	Normal deep veins lateral venous channels joining profunda and common iliac veins
-	Peripheral phlebogram	Normal deep veins Hunter canal incompetent perforating vein lateral venous trunk entering common iliac vein
+	Peripheral phlebogram direct injection	Normal deep veins incompetent perforating veins of calf antero-medial venous trunk
+	Peripheral phlebogram	Hypoplasia of deep veins of calf incompetent thigh perforating veins entering profunda vein lateral venous trunk joining common iliac vein
-	Peripheral phlebogram transosseous percalcaneal injection intraosseous peritrochanteric injection	Normal deep veins incompetent perforating veins of the calf lateral venous trunk joining common iliac vein
+	Peripheral phlebogram intraosseous per calcaneal injection intraosseous peritrochanteric injection	Normal deep veins incompetent perforating veins of the calf lateral venous trunk joining common iliac vein
-	Peripheral phlebogram direct injection R femoral injection L peritrochanteric injection	Normal deep veins of calf bent upper left femoral external and internal iliac veins lateral venous trunk entering right internal iliac vein
-	Peripheral phlebogram	Absent deep veins of calf lateral venous trunk joining femoral vein in mid thigh
-	Peripheral phlebogram	Absent deep veins lateral venous trunk in thigh passing medially to join femoral vein in upper thigh

T bl 2

Treatment & results

Case	Tree	Result
1	Leg	Improvement
2	Leg	Temporary improvement
3	N	
4	Embolism of arm	Improvement
5	Leg	Temporary improvement
6	Leg	Improvement
7	Leg	Improvement
8	Leg	Improvement
9	N	
10	Leg	Improvement
11	Relief of leg	Improvement
12	N	
13	N	
14	N	

adequate to demonstrate the whole deep venous system (LEA THOMAS *et coll* 1971, LEA THOMAS 1972). In 2 patients this was supplemented by direct injection of contrast into a superficial vein to show its deep connections (LEA THOMAS & ANDERSSON 1971). In addition to peripheral phlebography per iliac and p. trochanteric injection were required in one patient to demonstrate the whole of the deep venous system; combined p. trochanteric and per femoral techniques were employed in a second and bilateral per femoral in a third patient (LEA THOMAS & FLETCHER 1967). The technique used to demonstrate iliofemoral perforating vein has also been described (LEA THOMAS *et coll* 1972).

Arteriography was carried out by femoral arterial puncture and the use of a rapid series of films using an automatic film changer.

Results

In all cases extensive dilated superficial veins were demonstrated, not especially associated with the long and short saphenous groups (Figs 3, 8).

Eleven cases had large valveless dilated venous trunks usually situated on the lateral aspect of the leg (Figs 3, 4, 8 b, 7, 8). The dilated venous trunks entered the profunda vein (Fig. 3 a), the femoral vein or the veins of the pelvis (Figs 5, 6). They frequently had multiple drainage into the deep venous system (Figs 3 a, 4 c).



Fig 4 Case 8. Peripheral phlebogram of left leg: a) Lateral view of foot and ankle b) Perforating veins. A horizontal cross trunk (\rightarrow) c) Incompetent perforating veins (\rightarrow) connecting cross trunk with the deep veins

In seven cases enlarged perforating veins were demonstrated in the calf (Fig 4c). In addition to these there were often perforating veins joining the venous trunks to the profunda vein or the femoral vein (Fig 3a). These perforating veins were often incompetent.

In four patients the deep veins of the thigh and thigh were absent (Figs 2, 7). In two the femoral vein alone was absent (Fig 6) and in one patient the deep calf veins only were absent.

In one patient the whole of the deep venous system was hypoplastic as far as the upper femoral vein. In one patient there was a stenosis of the external iliac vein thought to be due to compression by a nearby artery and in another the left external and common iliac veins were occluded (Fig 6a).

In two patients the deep venous system appeared normal apart from incompetent perforating veins in the calf. The findings are summarised in Table 1.

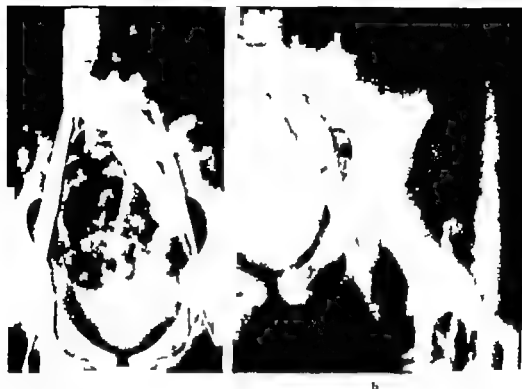


Fig. 5 (a, b). Bilateral perfromal phlebogram. (a) External iliac vein and ter iliac veins considerably dilated; superficial veins dilated. (b) Perigermal phlebogram. Large lateral venous trunk joining left common iliac vein.

Arteriography. All arteriographies were normal. In the later phases of the examination the deep veins could sometimes be faintly made out, giving further information as to the patency or otherwise of the deep venous system.

Conventional films of the affected limbs were taken in four patients. All showed thickening of the soft tissues, 2 lengthening of bones, 1 periostitis of the tibia and fibula and 1 phleboliths (Table 1).

Discussion

The clinical features of our patients were typical of the entity now generally accepted as the Klippel Trenaunay syndrome. In all but one patient, the lesions were present in only one lower limb and in the remaining patient, although the lesions were bilateral, they were more marked on the right side than on the left. Bilateral involvement has been previously described (Kuffer et coll. 1968) and



b

FIG 6 Case 1 (a) Combined right per femoral and left intraosseous pelvic phlebogram. Upper femoral and iliac veins absent on the left. Collateral veins bypass the occluded segment. (b) Direct injection phlebogram. A dilated shallow anomalous trunk draining into the right internal iliac vein.

even involvement of all 4 limbs (LAMAR et coll 1963). The cutaneous naevi were always noted at birth but tended to become more obvious with age. They were predominantly on one lower limb but extended in some instances onto the buttock and the lower thorax. The dilated superficial veins were usually extensive sometimes forming a plexiform network (Fig 9). There was increased length and size of the affected limb in most of our patients. There was no clinical evidence such as increased warmth, pulsating varicose, a thrill or bruit or a positive Brannan sign which would suggest the presence of an arteriovenous fistula. No early filling of veins was observed nor increased tortuosity of branches nor enlargement of the main arteries which would suggest arteriovenous shunting. As bilateral femoral arteriographies were carried out it was possible to compare the diameters of the arteries on both sides (Fig 9). Because there was no evidence of arteriovenous fistulas the cause of limb hypertrophy is not clear but hypertrophy has been attributed to venous stasis (SERVILLE 1943; PACK & MILLER 1950; LACROIX 1951; MALAN & PUGLIONISI 1964; WORTZEL 1966; BARIETY et coll 1967).

The aim of phlebography is to demonstrate as fully as possible the deep venous system in order to show its patency, any obstructing lesions and abnormal superficial channels.

In the presence of dilated superficial veins the demonstration of the deep venous system can prove difficult (KERT & GRISHMAN 1943; MEYERS & JONES

1955; MALAN & PUELIGNISI 1964; Editorial Trans. St. John Hosp. Derm. Soc. 1966). The most reliable method is intravenous phlebography from the medial malleolus (HARRISDAY 1968) but this method carries the hazard of necrosis of a developing epiphysis in young people. An intravenous phlebogram to show the iliac vein was used in one of our young patients (Case 10) without incident but it was resorted to as the only method available to fill the deep venous system in the presence of an occluded femoral vein (Fig. 6).

Factors which improve the chance of deep venous filling are injecting contrast toward the toes i.e. in an upstream direction so that the contrast passes through communicating veins in the dorsum of the foot directly into the deep venous system (HARRISDAY 1968). A steep table tilt and tight tourniquets around the ankle adjusted under screen control are also helpful. Care must be taken however when the deep venous system is absent or hypoplastic as the contrast medium may be trapped in the foot causing tissue damage which may lead to gangrene (IRA THOMAS 1970). Indirect phlebography i.e. injection of large volume of contrast (50 ml or more) into the femoral artery with follow through to the venous phase may give some additional information about the state of the deep venous system (IRA THOMAS & ANDREWS 1971).

The phlebographic findings in our patients are similar to those described by others. These included absence or hypoplasia of the deep venous system in whole or in part (SERVIELLE 1945; SERVIELLE et coll. 1957; LINDENBAUM 1965, 1971), venous obstruction caused by adjacent arteries (SERVIELLE et coll. 1957) and complete absence of a common and external iliac vein (SERVIELLE 1945; OLIVER 1955; SERVIELLE et coll. 1957; MALAN & PUELIGNISI 1964; LOULET & LUFF 1969).

The state of the deep venous system is fundamental to management. If an obstruction is present it may be relieved by surgical reconstruction as reported by others (SERVIELLE et coll. 1957; LINDENBAUM 1957). Such a surgically operable lesion is however rare. Stripping and tying of superficial varicose vein in patients with deep venous obstruction worsens the symptoms producing further varicose veins and oedema (FOSTER & KIRTLER 1959; MALAN & PUELIGNISI 1964; LINDENBAUM 1971). Such patients are best treated with simple supportive measures such as elastic stockings. Thus the most important aspect of the investigation of patients with Klippel Tronçonay syndrome is to demonstrate any abnormalities of the deep venous system.

Many attempts have been made to classify the angiodysplasias. GORDANICH & CAMPANACCI (1962) suggested a division into superficial and deep, localized or diffuse but did not distinguish between those with or without an arterial element. The long term prognosis in patients with a purely venous angioma is much better than that of a congenital arteriovenous fistula (MALAN & PUELIGNISI 1964; Irv



Fig 7



Fig 8



Fig 9

Fig 7 Case 13 Peripheral phlebogram right leg Dilated superficial veins on lateral aspect of leg Deep venous system absent in the calf

Fig 8 Case 14 Peripheral phlebogram of right leg Deep veins of the calf absent lateral venous trunk

Fig 9 Case 1 Peripheral phlebogram of right foot Extensive plexiform network of superficial veins

DESAURI 1965 Editorial Iran. St John Hosp Derm Soc 1964) It is therefore important to make a distinction between these groups. Recognizing this, MALAN & PIERCE (1961) separated off the venous dysplasias and subdivided them into four groups: phlebectasia, phlebangioma, phlebangioma-like and a combination of all three. An attempt to further simplify the classification of venous dysplasias has been suggested by LEE THOMAS & ANDREWS (1971). These authors suggest that angiographically there are two basic types: one in which the principal abnormality consists of dilated venous trunk and the other consisting mainly of cavernous space. For the former they use the term phlebectasia and for the latter venous angiomatosis. The Klippel-Trenaunay syndrome falls into the former group.

However the triad described by KLIPPEL & TRENAUNAY of unilateral varicose veins, cutaneous nevi and bony and soft tissue hypertrophy is a fairly well defined entity. For these reasons it is suggested that the term Klippel-Trenaunay syndrome should be retained.

Acknowledgements

We wish to thank J. J. B. Kinnmonth and M. E. B. Cockett for their participation in the phlebectasia lectures on 27th September 1971, reproduced by permission of the Editor, The American Journal of Roentgenology and Figure B by permission of the Editor of The British Journal of Plastic Surgery.

SUMMARY

The phlebectasia findings in 14 patients with Klippel-Trenaunay Syndrome are described. The most important finding is dilatation or hypoplasia of the deep venous system. Other findings include extensive varicosities, dilated venous trunk and enlargement of the venous sinus, interruption of superficial veins in the presence of a deep venous system, worsened symptoms if associated with the term Klippel-Trenaunay Syndrome should be retained but is played exclusively for patients with the triad of unilateral varicose veins, cutaneous nevi and hypertrophy of bone and soft tissues with no other abnormality.

ZUSAMMENFASSUNG

Die phlebektasieähnlichen Befunde bei 14 Patienten mit Klippel-Trenaunay-Syndrom werden beschrieben. Der wichtigste Befund ist die Dilatation oder die Hypoplasie des tiefen Venensystems. Andere Befunde umfassen extensive Varizen, Venenstämme und erweiterte perforierende Venen. Es wird hervorgehoben, dass eine Hohlraumphlebektasie der Hohlraum der Blutbahn der Patienten mit einem Klippel-Trenaunay-Syndrom vorzuzunehmen werden sollte. Eine Unterbrechung der oberflächlichen Venen im Gegenstand eines intakten tiefen Systems können die Symptome verschlechtern. Es wird weitergeklärt, dass der Begriff Klippel-Trenaunay-Syndrom beizubehalten jedoch nur bei den Patienten anzuwenden, bei denen die Triade der unilaterale Varizen, kutane Nevi und der Hypertrophie der Knochen und weichen Gewebe ohne anderen Befund vorliegt.

RÉSUMÉ

Description des signes angiographiques chez 14 malades atteints d'un syndrome de Klippel Trenaunay. Le signe le plus important est l'absence ou l'hypoplasie du système veineux profond. Les autres signes comprennent des veines variqueuses étendues, des troncs veineux dilatés et des veines perforantes dilatées. L'interruption chirurgicale des veines superficielles quand le système veineux profond est anormal peut aggraver les symptômes. Les auteurs pensent qu'il faut garder le terme de syndrome de Klippel Trenaunay mais le réserver exclusivement aux malades qui présentent la triade de veines variqueuses unilatérales, naevus cutanés et hypertrophie de l'os et des parties molles sans fistule artério-veineuse.

REFERENCES

- BARIET M, SERELLE M, POLLET J et RUFF F. Anomalies veineuses et dysplasies congénitales des membres. Bull. Soc. méd. Hôp. Paris 118 (1967) 39.
- BILGART H L and EVANSTEVE A C. Hemangioectatic hypertrophy and congenital phlebectasias. Arch. intern. Med. 49 (1932) 509.
- BOLARY G et BOUKTHOUJEL A. Le étirement cardiaque du syndrome de Klippel Trenaunay. Arch. Mal. Cœur 50 (1957) 676.
- COTTON L T and SYKES B J. The treatment of diffuse congenital arteriovenous fistula of the leg. Proc. roy. Soc. Med. 62 (1969) 245.
- CALLISTO T B. Hypertrophy of the leg with associated vascular abnormality (The Klippel Trenaunay syndrome). Report of a case. Med. J. Aust. 2 (1911) 773.
- DEMOIS F et PELICE P H. Communications artério-veineuses révélées par phlébographie ou angiographie d'angiomes type d syndrome de Klippel Trenaunay. Arch. belges Derm. 15 (1957) 199.
- Editorial. Klippel Trenaunay or Parkes Weber. Trans. St. John Hosp. Derm. Soc. 52 (1966) 272.
- FOSTER J H and KENTLEY J A. Unilateral lower extremity hypertrophy. Surg. Gynec. Obstet. 108 (1959) 35.
- GARCIA R F y VIERO CHICOTA M. Síndrome de Klippel Trenaunay (Presentación de 3 casos). (In Spanish.) Pten. méd. argent. 43 (1956) 3259.
- GORDON I F and CAMPANACCI M. Vascular hamartomata and infantile angioectatic osteohyperplasia of extremities. J. Bone Jt. Surg. 44 A (1962) 815.
- HALLIDAY P. Phlebography of the lower limb. Brit. J. Surg. 55 (1968) 220.
- HARRIS H E and WRIGHT O P. A case of hemangioectatic hypertrophy of limb and observations upon rate of growth in the presence of increased blood supply. Heart 15 929 (1914).
- KIPP M J and GRISMAN A. Diffuse genuine hemangioectatic hypertrophy of limb. J. Mt. Sin. Hosp. 11 145 (1912).
- KLIPPEL M et TRENAUNAY P. Du naevus osseus et cutané. Arch. gén. M. 183 (1900) 641.
- KLIPPEL M, STAREZYNSKI T E, GIROLAMI A M and GRABSTADT H. Coexistence of varicose osteo-hypertrophic nevus, hemangioectatic hypertrophy and thrombocytopenia (Klippel Trenaunay). H. J. Mt. Sin. Hosp. 11 145 (1912).
- LACHRY P. The organisation of bones. J. & A. Churchill Ltd. London 1951 p. 35. (Quoted by Meyers and Jones 1955).
- LAVAR L M, FARRER G A and O'QUINN S E. Klippel Trenaunay Weber syndrome. Arch. Derm. 91 (1965) 58.
- KLIPPEL M et TRENAUNAY P. Du naevus osseus et cutané. Arch. gén. M. 183 (1900) 641.
- KLIPPEL M, STAREZYNSKI T E, GIROLAMI A M and GRABSTADT H. Coexistence of varicose osteo-hypertrophic nevus, hemangioectatic hypertrophy and thrombocytopenia (Klippel Trenaunay). H. J. Mt. Sin. Hosp. 11 145 (1912).
- LACHRY P. The organisation of bones. J. & A. Churchill Ltd. London 1951 p. 35. (Quoted by Meyers and Jones 1955).
- LAVAR L M, FARRER G A and O'QUINN S E. Klippel Trenaunay Weber syndrome. Arch. Derm. 91 (1965) 58.

LANCERON P, L'ECLAUPE M B. Le syndrome de Klippel Trenaunay historique — Nosologie aspects cliniques et pathogeniques. *J Sci méd Lille* 88 (1970) 461

LEA THOMAS M C. Grene following, peripheral phlebography of the leg. *Brit J Radiol* 43 (1970) 578

— Phlebography. *Arch Surg*, 101 (1973) 145

— and LUTCHER F W L. The techniques of pelvic phlebography. *Clin Radiol* 18 (1967) 399

— and ANDERSON M R. Angiography in venous dysplasias of the limb. *Amer J Roent* 109 (1971) 742

— McALISTER A, ROSS D H and TONG H. A simplified technique of phlebography for the localisation of incompetent perforating veins of the legs. *Clin Radiol* 23 (1970) 486

— and TONG H. Simplified phlebography in deep venous thromboses. *Clin Radiol* 22 (1971) 490

LEIDER ALER S M. Klippel Trenaunay syndrome. *Ann Surg* 162 (1965) 303

— Congenital arteriovenous fistula and the Klippel Trenaunay syndrome. *Ann Sur* 174 (1971) 248

MALA E and LUTCHER A. Congenital angiodysplasia of the extremities. Not a congenital and late manifestation Venous dysplasia. *J cardiovascular Surg* 5 (1964) 87

MARTORELLI F and MONERRAT J. Atresia iliofemoral and Klippel Trenaunay syndrome. *Angiology* 13 (1962) 763

METZGER T F and JONES J M. Comprehensive surgical management of cavernous hemangioma of lower extremity with special reference to stripping surgery. *J Surg* 37 (1964) 184

NAZARRO P. Consideration su d un caso d'hemangioectasia h'peritrofica (Klippel Trenaunay Parkes-Weber). (In Italian). *Ann ital Derm Sif* 9 (1964) 156

ODA F T, McLELLAN J S, YEAGER C H, BURTO R W and MANSON A R. Vascular anomalies of the extremity associated with abnormal growth. *Amer Surg* 28 (1962) 775

OLIVIER C L. Les lésions symptomatiques d'malformations vasculaires. *Essai de classification*. *Presse méd* 86 (1955) 1822

PAGE G T and MILLER T H. Hemangiomas: classification, diagnosis and treatment. *Angiology* 1 (1950) 405

PARADES WILMER F. Angioma formation in connection with hypertrophy of limbs and bone hypertrophy. *Brit J Derm* 19 (1907) 231

— Hemangioectatic hypertrophy of limbs — congenital phlebotomectomies and some congenital arthroscopies. *Brit J Child Dis* 15 (1918) 13

— Further rare disease and debatable subjects. Staples Press Ltd. London 1949

PECK M E. Obstructive anomalies of the iliac vein associated with growth shortening in the palatal extremity. *Ann Surg* 146 (1957) 619

POULET J et RUFF F. Les dysplasies vasculaires congénitales des membres. *Presse méd* 77 (1969) 163

SERVILLE M. La angiographie telle nous permet de démembrer le syndrome de Klippel et Trenaunay et l'hémangioectasie hypertrophique de Parkes Weber. *Presse méd* 53 (1945) 333

— ALBEAUX FERNET M, LABORDE E, CHARRAT J et ROUGEUILLE J. Lésions des vaisseaux lymphatiques dans les malformations congénitales des veines profondes. *Presse méd* 65 (1957) 531

— Syndrome de Klippel Trenaunay. *Presse méd* 72 (1964) 3323

WORTZEL M H. Klippel Trenaunay Parkes Weber syndrome. *J med Soc N J* 63 (1966) 420

SCINTIGRAPHY AS A SCREENING TEST FOR CARCINOMA OF THE PANCREAS

K. WATANABE, K. KAWAHIRA and K. MATSUURA

Carcinoma of the pancreas is difficult to detect sufficiently early for successful surgical treatment (CAYTEL & PYTREA 1949; DENNIS et coll 1956; PORTER 1958) the symptoms and signs are nonspecific and no simple and accurate means of diagnosis is available. Methods such as pancreatic duodenography, duodenal fibercopy, selective abdominal angiography and splenoportography are all difficult to perform. A more simple yet accurate examination is available in scintigraphy although it carries its own problems. Only 4 to 7 per cent of the dose of ^{75}Se -Selenomethionine administered is taken up by the gland (BLAU & MANASSE 1961; BLAU 1961, 1964; LAP & RAZZAK 1969) most of it being concentrated in the liver. The liver and pancreas are in close anatomic relationship so that it is often difficult to separate them in a scintigram; in addition the pancreas lies deep in the body so that a clear outline is hard to obtain.

This investigation was performed in patients with various pancreatic disorders in order to obtain more information on the clinical significance of such an examination as a screening test for carcinoma of the pancreas.

Table I
Classification of cases

Diagnosis	Verified Proven cases	Clinical diagnosis	Total
Carcinoma	31	8	39
Pancreatitis	10	33	43
Normal	3	9	
Others	19	13	32
Pancreatic cyst	4	0	4
Islet cell tumour		0	
Cholesterol cyst	4	0	4
Retropertoneal tumour	5	0	
Pancreatic metastases	4		
Diabetes mellitus	0	11	11
Total	83	113	196

Material The various pancreatic disorders of the 196 cases examined are classified in Table I. The diagnosis of 83 of the cases was confirmed at operation or autopsy while this was suggested in 113 cases by symptoms, signs and various laboratory examinations. Thirty-nine cases with jaundice, ascites and an abdominal mass were considered as having carcinoma of the pancreas and diagnosed by roentgen examination and pancreatic duodenography; in 11 of these the diagnosis was confirmed by histology. Pancreatitis was in 43 cases diagnosed by roentgen examination, serum and urinary amylase activity and the pancreatic secretin test; in 10 of these cases it was confirmed by histology. A retroperitoneal mass, a pancreatic cyst, an insulinoma and other malignant metastases were revealed at laparotomy.

Method A dose of 250 μ Ci 75 Se Selenomethionine was administered intravenously and followed 30 minutes later by a scintigram of the pancreas. The patient lay supine with the scinticamera (Nuclear Chicago Pho/Gamma III) set at an angle of 5° from the vertical and directed toward the head; the exposure was preset for 1.2×10^5 counts. Hepatic scintigraphy was then carried out following the intravenous injection of 199 Au colloid or 99m Tc colloid.

Scintigrams were divided into five groups: localized defect, total defect, faint demonstration, displacement, and normal. A normal scintigram of the pancreas is featured in Fig. 1. A localized defect scintigram indicated a partial defect in the normal contour of the pancreas (Fig. 2). A total defect meant that no



Fig 1 Normal pancreas

Fig 2 Localized defect
(Carcinoma of pancreas)

Fig 3 Total defect (Carcinoma of pancreas)

radioisotope uptake was observed in the pancreatic region (Fig 3). Fig 4 presents a faint scintigram of the pancreas with less uptake of radioisotope compared with that of the normal. Displacement of the pancreatic scintigram is evident in Fig 5.

Results

Twentytwo of the 39 cases of carcinoma of the pancreas had a localized defect in the pancreatic scintigram. A total defect occurred in 14 cases indicating an abnormal scintigram in 92 per cent of the cases. The remaining 3 cases (8 per cent) failed to present any abnormality.

The scintigram was normal in 19 cases (44 per cent) and presented a localized defect in 8 (19 per cent), faint demonstration in 7 (17 per cent) and a total defect in 9 (21 per cent) of the 43 patients with pancreatitis. Normal scintigrams were obtained in 73 cases (89 per cent), faint demonstration in 6 (7.3 per cent), total defect in 2 (2.4 per cent) and displacement in 1 case (1.2 per cent) of the normal part of the material.

The 38 cases with a localized defect were evaluated. Twentytwo cases (58 per cent) had carcinoma, 8 (21 per cent) pancreatitis and the remaining 8 cases had other disorders such as pancreatic islet tumours, metastases and retroperitoneal tumour. No cases with a localized defect were normal.

Of 16 cases with faint scintigrams, 7 cases (44 per cent) had pancreatitis, 6 (37 per cent) were normal and 3 (19 per cent) had diabetes. No case of carcinoma of the pancreas had a faint scintigram.

A total of 33 cases with a total defect in the pancreatic scintigram was made up of 14 cases (42 per cent) of pancreatic carcinoma, 9 cases (27 per cent) of



Fig. 4. Failure demonstration
(chronic pancreatitis)



Fig. 5. Displacement (Retroperitoneal tumour)

pancreatitis and 8 cases (24 per cent) of other disorders such as diabetes, a retroperitoneal tumour and metastases from other organs. The 9 cases with displacement of the scintigram consisted of 3 of pancreatic cyst, 3 of obstruction of the bile duct, 2 of retroperitoneal tumour and 1 normal case.

The 100 cases with normal scintigrams were analyzed. 73 cases (73 per cent) were free from pancreatic disease. 19 cases (19 per cent) had pancreatitis and 8 cases (8 per cent) had other pancreatic disorders.

The site of the carcinoma of the pancreas established at operation or autopsy was compared with the scintigraphic findings in 28 cases (Table 2). Complete agreement between the situation of the neoplasm and that of the defect in the scintigram was evident in 10 out of 28 cases (36 per cent). The size of the defect was usually greater than that of the tumour.

Table 2

Diagnostic accuracy of the localization of pancreatic carcinoma by scintiscanner (total of 98 cases)

Localized defect					Non visualized	Normal findings
Head	Body	Tail	Head/body	Body/tail		

Head

Body

Tail

Head/body

Body/tail

Total pancreas

Correct diagnosis 10/28 36

Carcinoma of the head of the pancreas produced a total defect in the scintigram in 5 out of 8 cases, a localized defect being caused in 2 and a normal scintigram occurred in one case. Four cases with carcinoma of the body of the pancreas were made up of 1 case of total defect and 3 suggesting localized defects in the head or tail regions.

Discussion

No reliable means for early detection of carcinoma of the pancreas is available at present. Roentgen examination of the upper part of the digestive tract is however generally considered the method of choice for the examination of cases of possible carcinoma of this gland, making the detection rate 50 to 60 per cent (GULLIX 1959, GOSWITZ 1961, EYLER et coll 1962, ANSARI & BURCH 1970). It is also well recognized that pancreatic scintigraphy is useful in the diagnosis (SODER 1966, RODRIGUEZ ANTUNEZ et coll 1966, BROWN 1968, EATON et coll 1968, FINA et coll 1969, HATCHETTE et coll 1972, HESLIP & OVERTON 1971).

The present investigation revealed that 36 (92 per cent) out of 39 cases of carcinoma of the pancreas had abnormal scintigrams with localized or total defects. This finding agrees well with those of previous workers (BROWN, EATON et coll, FINA et coll, HATCHETTE et coll, HESLIP & OVERTON, RODRIGUEZ ANTUNEZ et coll 1966, SODER 1966). The results must however be revised with due consideration to the extent or the size of the growth. A large pancreatic carcinoma is relatively easy to discover. Although the detection of a neoplasm 2 cm in diameter by scintigraphy has been reported possible (LIEVENDIAHL & KIVIST 1970, SODER 1964) the present 2 cases with a carcinoma over this size were not successfully demonstrated. The malignant tissue was situated in the region of the body and tail of the pancreas and the scintigrams were interpreted as being due to a short pancreas; this indicates the difficulty in recognizing a localized defect in scintigrams and is particularly true with such tumours at an early stage. The sensitivity of scintigraph in revealing early carcinoma is highly doubtful although the possibility of this method being of value in the diagnosis was well supported by the present investigation which disclosed that over 90 per cent of the cases affected had abnormal pancreatic scintigrams.

Twentyfive cases of 38 with a localized defect and 16 of 33 cases with a total defect had a malignant condition of the pancreas. Approximately 57 per cent of the cases with localized or total defect with pancreatic scintigram therefore had a malignant growth; the other 43 per cent of these abnormal scintigrams was however due to disorders other than a neoplasm supporting the previous reports of 15 to 50 per cent for false positive results (BROWN, RODRIGUEZ ANTUNEZ et coll 1966, SODER 1966). The number of false negative scintigram of

carcinoma of the pancreas is however low. A normal scintigram excludes a new growth (RODRIGUEZ ANTUNEZ 1968 BROWN, BURDINE & HAYNE 1965 FINK et coll. LIEWENDAHIL & KAIST 1970 LANDMAN et coll. 1971 STAAB et coll. 1971). The conclusion may therefore be reached that scintigraphy constitutes a most useful screening test.

The utilization of scintigraphy for localization as well as for the determination of tumour size was evaluated in the present work. For these purposes it proved of less value. Carcinoma of the gland is usually complicated by pancreatitis.

BARTHOLOMEW et coll. 1958 PALLINO NETTO et coll. 1960 LORBER & CHIFFY 1969) so that a defect larger than the true size of the tumour is obtained. Six out of 8 cases with carcinoma of the head had a total defect.

The potential genetic damage in the use of a relatively high gonad dose of ^{131}I -Selenomethionine (SODFE et coll. 1965) administered to patient with possible pancreatic carcinoma must be borne in mind. The incidence of carcinoma is more common however in the age group of 60 years and over (ANSARI & BURCH, ACKERMAN & DEL REGATO 1962 LOWE & PALMER 1967) consequently the hereditary effects of the test may perhaps be ignored.

SUMMARY

An investigation was performed in 196 cases to evaluate scintigraphy as a screening test in the diagnosis of carcinoma of the pancreas. Ninety per cent of 39 cases of malignancy had a localized or total defect in the scintigram although the false positive rate of the material was 43 per cent. On the other hand normal scintigrams excluded carcinoma. The test appears to constitute a useful means for the diagnosis in this condition.

ZUSAMMENFASSUNG

Es wurde eine Untersuchung an 196 Fällen vorgenommen, in die Scintigraphie als Screening-Test für die Diagnose eines Pankreaskarzinoms klarzulegen. 92 % der 39 Fälle mit einem malignen Geschehen hatten einen lokalisierten oder totalen Defekt im Scintigramm, wobei die Frequenz falscher positiver Fälle des Materials 43 % betrug. Andererseits schloß ein normales Scintigramm ein Karzinom aus. Dieser Test scheint zu bestätigen, dass die Scintigraphie ein brauchbares Verfahren für die Diagnose dieser Erkrankung darstellt.

RÉSUMÉ

Les auteurs ont fait un travail de recherche sur 196 cas pour apprécier l'intérêt de la scintigraphie comme épreuve de dépistage dans le diagnostic du cancer du pancréas. Quatre-vingt-douze pour cent des 39 cas de tumeur maligne présentaient une zone localisée ou totale de défaut d'activité sur le scintigramme, cependant la proportion de faux positifs pour la série était de 43 pour cent. D'autre part des scintigrammes normaux excluent un cancer. Cette épreuve paraît constituer un moyen utile pour le diagnostic de cette affection.

REFERENCES

- ACKERMAN L. V. and DETTLESON J. V. *Cancer* Third edition p 739 C. V. Mosby, Saint Louis 1962
- ANSARI A. and BURCH G. E. A correlative study of proven carcinoma of the pancreas in 83 patients *Amer J Gastroint* 50 (1970) 456
- BARTOLOMEW L. G. GROSS J. B. and CONNOR T. W. Carcinoma of the pancreas associated with chronic relapsing pancreatitis *Gastroenterology* 35 (1958) 473
- BLAU M. Biochemistry of ^{75}Se Selenomethionine and ^{75}Se Selenocysteine *Biochim biophys Acta* 49 (1961) 389
- *Pancreatic scanning with ^{75}Se Selenomethionine* *Medical Radio isotope Scanning IAEA* 2 (1964) 775
- and MCKEE R. F. The pancreatic specificity of ^{75}Se Selenomethionine *J Nucl Med* (1961) 102
- BROWN P. W. Scintillography in the diagnosis of pancreatic disease *Lancet* 1 (1968) 160
- BURKH T. J. A. and HAYES T. I. Diagnosis of pancreatic carcinoma by photoscanning *J Amer med Ass* 194 (1965) 979
- CITTEL R. B. and PYTZEL L. J. An appraisal of pancreaticoduodenal resection: A follow up study of 61 cases *Ann Surg* 129 (1949) 840
- DEVIN C. BROOKLYN N. Y. and VARGO R. L. Survival for more than five years after pancreaticoduodenectomy for cancers of the ampulla and pancreatic head *Surgery* 39 (1956) 97
- EARLY P. J. RAZZAL M. A. and SODER D. B. *Textbook of Nuclear Medicine Technology* p 311 C. V. Mosby, Saint Louis 1969
- EATON S. B. FLEISCHLI D. J. LOLLARD J. J. et coll. Comparison of current radiologic approaches to the diagnosis of pancreatic disease *New Engl J Med* 279 (1968) 389
- EYLER W. R. CLARK M. D. and RIAS R. L. Evaluation of roentgen signs of pancreatic enlargement *J Amer med Ass* 181 (1962) 967
- FIDE S. BEN PORATH M. JACOBSON B. et coll. Current status of dual-channel pancreas scanning *J Nucl Med* 10 (1969) 78
- GOSWITZ J. T. Carcinoma of pancreas: Comprehensive review of 173 cases emphasizing inadequacy of our diagnostic technique *Ohio St med J* 57 (1961) 1255
- GULLICK H. D. Carcinoma of pancreas: Review and critical study of 100 cases *Medicine* 38 (1959) 47
- HATCHETTE J. H. SMILGER S. E. and MCGRAW P. J. Scintiphotos of the pancreas: Analysis of 134 studies *J Nucl Med* 13 (1972) 51
- HERRI P. G. and OVERTON T. R. The use of radioisotope scanning in the investigation of suspected carcinoma of the pancreas *Amer J Roentgenol* 112 (1971) 667
- LORDMAN S. POLCYN R. F. and GOTTSHALK A. Pancreas imaging — Is it worth it? *Radiology* 100 (1971) 631
- LIEVENDIAHL H. and HERR C. Evaluation of pancreatic scanning *Acta med scand* 180 (1970) 75
- LOHMEYER S. H. and CHRY W. V. *Gastroenterologic Medicine* Moses Paulson p 1105 L. & F. Lippincott Philadelphia 1969
- LOWE C. W. and PALMER E. L. Carcinoma of pancreas: An analysis of 100 patients *Amer J Gastroint* 47 (1964) 412
- PACILLO-VITO A. DREILING D. A. and BARNOWSKY I. D. The relationship between pancreatic calcification and cancer of the pancreas *Ann Surg* 151 (1960) 530

- PORTER M. R. Carcinoma of the pancreaticoduodenal area: operability and choice of procedure. *Ann Surg* 148 (1958) 711
- RODRIGUEZ AVILA A. Photoscanning of the pancreas. *J Amer med Ass* 70 (1968) 347
- FILON F. J. SULLIVAN JR B. H. and BROWN C. H. Photoscanning: diagnosis of carcinoma of the pancreas. *Ann intern Med* 63 (1966) 730
- STAAB E. A. BARR O. A. KLETTE F. C. and BRILL A. B. Pancreatic radionuclide imaging using electronic subtraction technique. *Radiology* 79 (1971) 633
- SOMER D. B. Radionuclide scanning of the pancreas with Selenomethionine (^{75}Se). *Radiology* 83 (1964) 910
- Pancreatic scanning. *Radiology* 87 (1966) 641
- REYNOLDS L. HILL C. and DISTENFELD B. Dosimetry of Selenomethionine (^{75}Se) for pancreatic scanning. *Nucleonics* 73 (1965) 78

RADIOLOGIC DIAGNOSIS OF ILEAL CARCINOID TUMOURS

E BOIJSEN, J KAUBE and U TILÉN

Carcinoid tumours arise from the argentaffin cells of the gastrointestinal tract. They may be located anywhere from the cardia to the rectum and originate in any tissue derived from the primitive endoderm. Carcinoid is a slowly growing, well delineated tumour with a diameter of 0.5 to 3 cm, usually situated in the submucosa of the bowel wall (MOERTEL et coll 1961, SANDERS & AXTELL 1964, SIMPSON 1969 and others). Multiple small bowel carcinoids are present in some 25 per cent of cases. About 3 000 carcinoid tumours have been reported, some 45 per cent of which were in the appendix and almost 30 per cent in the jejunum ileum (DARLE 1972).

Despite the fact that the primary growth arising from the small bowel wall is small, extensive local lymph node involvement and large hepatic metastases often occur. The Swedish Cancer Registry (1971) recorded metastases in about 40 per cent of cases. The highest frequencies were listed in colonic, appendix ex-

Supported by the Swedish Medical Research Council. Submitted for publication 13 November 1972.

cluded) and ileal carcinoids 66 per cent and 53 per cent respectively. MORTZL et coll (1961) reported a definite relationship between the size of the primary neoplasm and the presence of metastases. Those carcinoids that originate from the appendix seldom produce metastases (MORTZL et coll 1968).

Some carcinoid tumours cause a mild form of diarrhoea. Most of them however produce no symptoms and are therefore frequently found incidentally at autopsy. Carcinoids may also lead to intestinal obstruction which is usually secondary to a fibroplastic change in the mesentery and adhesions. Less often the main symptom is haemorrhage. The origin of bleeding may be the tumour itself, ischaemic ileal necrosis due to involvement of mesenteric vessels or ulceration of the stomach or duodenum (MACDONALD 1956; DARLING & WELCH 1959; GOOD 1963; ANTHONY & DRURY 1970; HORSLEY & BAUER 1970). A malabsorption syndrome with steatorrhoea observed by KOWLESSAR et coll (1959) was thought to be secondary to local carcinoid metastases causing occlusion of mesenteric veins.

The carcinoid syndrome is produced by the release of 5-hydroxytryptamine (serotonin) from the metastases. It is characterized by intestinal signs, valvular disease of the right heart, peripheral vasomotor symptoms and signs, and rashes (THORSON et coll 1954 and others).

The diagnosis of a carcinoid tumour of the small bowel may be made by a barium examination. A combination of linked bowel loops and small intraluminal filling defects are typical (MILLER & HERRMANN 1942). KOWLESSAR et coll (1959) and HUDSON & MAROULIS (1961) observed that occlusions of mesenteric veins by the neoplasm cause oedema of mucosal folds which at small bowel examination may give the appearances of regional enteritis or sprue. The similarity between the small bowel changes in Crohn's disease and carcinoid growths was also reported by STARK et coll (1961) and WOOD et coll (1970). Despite the fact that these changes may occur in ileal carcinoids, a correct pre-operative diagnosis is seldom made. The reason for this is that most lesions cause not only the above changes but produce minor alterations that are not recognised as arising from carcinoids (BLUTH 1960; GOOD 1963; HUDSON & MAROULIS 1964).

The angiographic appearances in two cases of ileal carcinoids were described in 1966 (REUTER & BOIJSEN). The characteristic findings seemed to be the radiating arrangement of the vasa recta and the smaller intramesenteric arteries due to retraction of the mesentery and narrowing or occlusion of mesenteric arteries and veins. Since then these findings have been verified in additional reports (MARSHALL & LINDNER 1970; BOIJSEN 1971; SHIMAKI et coll 1971; CLAPS et coll 1972). The same changes were not observed in one case of a gastric carcinoid (ANDERSEN et coll 1971).

Angiography was reported in a few patients with hepatic metastases from carcinoids (LUDWIG *et coll* 1966 NEUBER *et coll* 1966) the metastases were generally very vascular.

The preoperative diagnosis of carcinoid tumours of the gastrointestinal tract thus appears seldom to be made unless the rare syndrome is present. Even then it may be impossible to locate the primary tumour by a barium examination of the small bowel despite the fact that it is recognised that ileal carcinoids are almost exclusively responsible for the syndrome. The few reports on the angiographic findings in carcinoid tumours do not permit of definite diagnostic conclusions. The present investigation may therefore add further experience, mainly in angiography, regarding both the primary ileal carcinoid and its local and distant growths.

Material and Methods A total of 15 patients (9 males, 6 females) aged from 32 to 75 with proven carcinoid tumours of the ileum were examined over a period of seven years (1964 to 1971). Three of these have been reported previously (REUTER & BOIJSEN 1966 BOIJSEN 1971). The main symptoms and signs were diarrhoea in 11 patients, abdominal pain in 12, weight loss in 6 and gastrointestinal bleeding in 3 patients. Two patients had the malabsorption syndrome with steatorrhoea. The 5 HIAA at the time of the radiologic examination was elevated in all 11 patients who underwent this test. 9 of these had signs and symptoms of flushing. Survey films of the abdomen were always available and a barium examination of the small bowel was performed in 12 patients.

Angiography of the superior mesenteric artery was carried out in all 15 patients and celiac or hepatic angiography in 12 patients. The indications for angiography varied: these in 4 patients being a palpable abdominal mass and bowel obstruction; in 2 patients the indication was acute gastrointestinal bleeding. The presence of carcinoid metastases were known before angiography in 7 patients, by fine needle biopsy of the liver in 5, of an axillary lymph node in one and of a tumour of the sterno-costal border in one patient. The discovery of malignancy was quite unexpected in 2 patients: one was examined by angiography because of hepatic cirrhosis and portal hypertension and the other for persistent diarrhoea.

Results

All 15 carcinoid tumours were in the terminal part of the ileum. The size of the primary growth varied between 1 cm and 3 cm in the 12 operation specimens available for close examination. Multiple primary tumours were present in 3 patients. All patients had metastases in the mesenteric lymph node and 11 had metastases in the liver.

cluded) and ileal carcinoids 66 per cent and 53 per cent, respectively. MOERTEL et coll (1961) reported a definite relationship between the size of the primary neoplasm and the presence of metastases. Those carcinoids that originate from the appendix seldom produce metastases (MOERTEL et coll 1968).

Some carcinoid tumours cause a mild form of diarrhoea. Most of them however produce no symptoms and are therefore frequently found incidentally at autopsy. Carcinoids may also lead to intestinal obstruction, which is usually secondary to a fibroplastic change in the mesentery and adhesions. Less often the main symptom is haemorrhage. The origin of bleeding may be the tumour itself, ischaemic ileal necrosis due to involvement of mesenteric vessels or ulceration of the stomach or duodenum (MACDONALD 1956; DARLING & WELCH 1959; GOOD 1963; ANTHONY & DRURY 1970; HORSLEY & BAKER 1970). A malabsorption syndrome with steatorrhoea observed by HOWLESSAR et coll (1959) was thought to be secondary to local carcinoid metastases causing occlusion of mesenteric veins.

The carcinoid syndrome is produced by the release of 5 hydroxytryptamine (serotonin) from the metastases. It is characterized by intestinal signs, valvular disease of the right heart, peripheral vasomotor symptoms and signs, and cyanosis (THORSON et coll 1954 and others).

The diagnosis of a carcinoid tumour of the small bowel may be made by a barium examination. A combination of linked bowel loops and small intraluminal filling defects are typical (MILLER & HERRMANN 1942). HOWLESAR et coll (1959) and HUDSON & MAROULIS (1964) observed that occlusion of mesenteric veins by the neoplasm cause oedema of mucosal folds which at small bowel examination may give the appearance of regional enteritis or sprue. The similarity between the small bowel changes in Crohn's disease and carcinoid growths was also reported by STARK et coll (1961) and WOOD et coll (1970). Despite the fact that these changes may occur in ileal carcinoids a correct pre-operative diagnosis is seldom made. The reason for this is that most lesions cause not only the above changes but produce minor alterations that are not recognised as arising from carcinoids (BLUTH 1960; GOOD 1963; HUDSON & MAROULIS 1964).

The angiographic appearances in two cases of ileal carcinoids were described in 1966 (REUTER & BOIJSEN). The characteristic findings seemed to be the radiating arrangement of the vasa recta and the smaller intramesenteric arteries due to retraction of the mesentery and narrowing or occlusion of mesenteric arteries and veins. Since then these findings have been verified in additional reports (MARSHACK & LINDNER 1970; BOIJSEN 1971; SHUMKIN et coll 1971; CLAPS et coll 1972). The same changes were not observed in one case of a gastric carcinoid (ANDERSEN et coll 1971).

Angiography was reported in a few patients with hepatic metastases from carcinoids (LUDEN *et coll* 1966 NEZESAR *et coll* 1966) the metastases were generally very vascular.

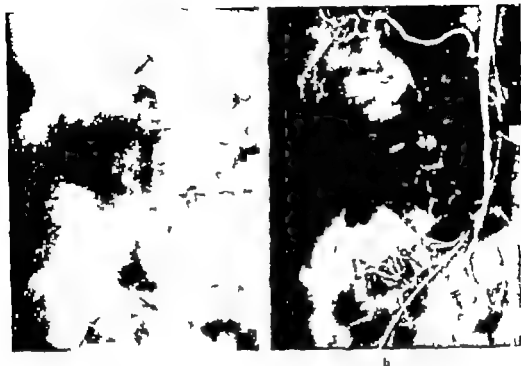
The preoperative diagnosis of carcinoid tumours of the gastrointestinal tract thus appears seldom to be made unless the rare syndrome is present. Even then it may be impossible to locate the primary tumour by a barium examination of the small bowel despite the fact that it is recognised that ileal carcinoids are almost exclusively responsible for the syndrome. The few reports on the angiographic findings in carcinoid tumours do not permit of definite diagnostic conclusions. The present investigation may therefore add further experience, mainly in angiography regarding both the primary ileal carcinoid and its local and distant growths.

Material and Methods. A total of 15 patients (9 males, 6 females) aged from 32 to 75 with proven carcinoid tumours of the ileum were examined over a period of seven years (1964 to 1971). Three of these have been reported previously (REUTER & BOJSEN 1966 BOJSEN 1971). The main symptoms and signs were diarrhoea in 11 patients, abdominal pain in 12, weight loss in 11 and gastrointestinal bleeding in 3 patients. Two patients had the malabsorption syndrome with steatorrhoea. The 5 HIAA at the time of the radiologic examination was elevated in all 11 patients who underwent this test. 9 of these had signs and symptoms of flushing. Survey films of the abdomen were always available and a barium examination of the small bowel was performed in 12 patients.

Angiography of the superior mesenteric artery was carried out in all 15 patients and celiac or hepatic angiography in 12 patients. The indications for angiography varied: these in 4 patients being a palpable abdominal mass and bowel obstruction; in 2 patients the indication was acute gastrointestinal bleeding. The presence of carcinoid metastases were known before angiography in 7 patients by fine needle biopsy of the liver in 5, of an axillary lymph node in one and of a tumour of the sterno-costal border in one patient. The discovery of malignancy was quite unexpected in 2 patients: one was examined by angiography because of hepatic cirrhosis and portal hypertension and the other for persistent diarrhoea.

Results

All 15 carcinoid tumours were in the terminal part of the ileum. The size of the primary growth varied between 1 cm and 3 cm in the 12 operation specimens available for close examination. Multiple primary tumours were present in 3 patients. All patients had metastases in the mesenteric lymph nodes and 11 had metastases in the liver.



b

Fig. 1. a) Preliminary film. Two calcifications: one in lower quadrant (\rightarrow) the other in medial part of left lobe of liver (\Rightarrow). b) Superior mesenteric angiograph: arterial phase. Main branches of the distal ileal arteries occluded (\rightarrow). More peripheral branches arranged in stellate manner pointing at the site of arterial occlusions and calcifications. Ileal artery (\Rightarrow) arising from ileo-colic artery, dilated but occluded at periphery. Tortuous collateral arteries in mesentery. c) Celase angiography late arterial phase. Richly vascularized metastases with one of the calcifications and several small nodular metastases in left hepatic lobe. Autopsy one year later disclosed carcinoma in the distal ileum with metastases to mesenteric lymph nodes and liver.





b



Fig. Woman with mass in lower abdomen. a) Small bowel examination. Distal ileal loops dilated and arranged around a soft tissue mass containing no small calcifications (→). Small bowel constricted (←→). b) Superior mesenteric angiography. arterial phase. Vasa recta and the intra mesenteric small arterial arcades of terminal ileum infiltrated, occluded and in stellate formation. Ileal artery (←→) arising from the ileocolic artery dilated secondary to occlusion of distal branches of the superior mesenteric artery, tortuous collateral arteries but no neoplastic masses. Proximal part of ileocolic artery and jejunal branches have slight luminal indentations due to arterial infiltration by proximal spread of lesion. c) Venous phase. Ileal and jejunal veins dilated and tortuous. No masses occluded or calcifications. d) Post-operative small bowel examination. Ileal caecum normal. Stricture of terminal ileum. Multiple lymph node metastases in the adjacent mesentery.



a



b

Fig. 3. Woman with mass in lower abdomen. a) Slightly dilated distal ileal loops with large and several smaller masses (\rightarrow). b) Angiography, preliminary film. Two calcifications and calcified (m); b) side evident. c) Superior mesenteric angiography, subtraction film. The calcifications were close to the centre of retraction of the mesentery as observed from the tortuous collateral arteries representing the centre of the tumour with dilated bowel arteries. First part of ileocolic artery (\rightarrow) not infiltrated and its ileal branch (\rightarrow) dilated the latter as well as distal branches of superior mesenteric artery occluded. Operation disclosed tumour in the centre of the mesenteric retraction. Some 40 submucosal carcinoid tumours were present in the distal ileum at autopsy four days later.

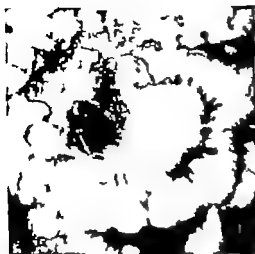


Conventional films of the abdomen before angiography revealed a soft tissue mass in the right lower abdomen in those patients in whom it was palpable. Calcifications were evident in the area and when the preliminary films were compared with the angiographic ones they proved to be in the centre of the retracted mesentery or close to it in 7 patients (Figs 1-2-3). The calcifications had not the lobulated appearances observed in healed tuberculous lymphadenitis and were as a rule almost spheric and smooth. Most varied in size from 4 mm to 6 mm the largest measuring 10 mm by 15 mm. One or two calcifications usually occurred in every patient. The tumour area of one patient had however four calcifications, each with a diameter of 4 mm. The pelvic bones in 5 patients tended to mask and obscure the calcifications (Fig. 1). In one patient a metastatic lesion in the liver was partly calcified (Fig. 1).

A barium investigation of the small bowel was negative in 3 of the 12 patients examined. In the remaining 9 patients a varying degree and type of dilatation of the distal ileal loops was observed. Slight widening combined with moderate mucosal changes and flocculation of barium as occurs in sprue were the only minor bowel abnormalities in 2 patients. Dilatation due to obstruction (Fig. 2) and bowel wall destruction or retraction of the mesentery (Figs 3-4) were other forms of intestinal widening. Marked kinking and deformation of the bowel due to fibroplastic retraction of the mesentery were present in 6 patients. These were combined with filling defects or partial strictures caused by the primary or secondary local growth.

The primary carcinoid mass was evident but did not produce any obstruction of the bowel or retraction of the mesentery in 2 other patients (Fig. 5). Vascular changes at superior mesenteric angiography suggested a carcinoid neoplasm of the ileum in 14 of the 15 patients. The most obvious change—the arrangement of the vasa recta and the intramesenteric ileal arcades in a radiating manner—was present in 10 patients (Figs 1 to 4 and 6). Stellate appearances were suggested in 2 patients but in another with definite signs of shrinkage of the mesentery (Fig. 5) no such appearances were evident. A slight tendency towards shrinkage and signs of adhesions were recorded in 2 patients (Fig. 7).

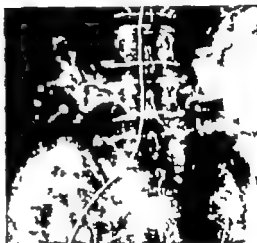
Arterial wall infiltration—either smooth or irregular—was invariably present and ranged from slight narrowing to complete occlusion. This occurred both at the level of the growth in the vasa recta and in the small intramesenteric as well as the main branches of the superior mesenteric artery. The arterial changes suggested fibromuscular hyperplasia in one patient (Fig. 4). When present the occlusions were always situated in the distal ileal arteries and the ileal branch arising from the ileocolic artery was frequently (11 patients) dilated and acting as a collateral artery. The same artery was also often occluded in the tumour area (Figs 1 to 4 and 6). Narrowing of these arteries at some distance from the



b

Fig 4 Woman with mass lower abdomen

a) Marked local stenosis with absence of normal mucro polypoid lesion (→) present in terminal ileum b) Superior mesenteric arteriogram arterial phase Distal part of superior mesenteric artery and its branches infiltrated and tortuous with appearances of fibromuscular hyperplasia Collateral arterial supply from distal jejunal arteries (→) as well as from ileal artery (←) arising from ileocolic artery Stellate arrangement c) Venous phase Occlusion of ems due to growth epous collaterals over right colic ems (↔) Operation curcoid and many small satellite tumours infiltrating the entire bowel wall and extending into the mesentery Malignancy in dilated lymphatics



primary growth most frequently occurred in the first part of the ileo-colic artery (Figs 2, 3 and 5 to 7). This proximal narrowing was always combined with marked lymph node invasion.

Tortuous arteries representing collaterals were observed in 14 patients. They bore a certain similarity to tumour vessels but neoplastic neo-vascularity was never defined.

Accumulation of contrast medium within the growth was marked in 3 (Figs 1, 4) and slight in 4 patients. The area of dense accumulation was approximately 5 cm in diameter revealing that the primary growth and the local metastases



b



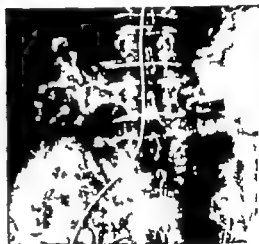
Fig 5 Fine needle biopsy suggested metastases from carcinoid 5-HIA elevated) Probable growth in terminal ileum (→) with the ileocecal ah swollen and the caecum compressed by an extrinsic mass b) Superior mesenteric angiography. Infiltration of ileocolic artery in its ileal branch (←→) as well as ileal arteries arising from the superior mesenteric no stielate appearances The tortuous irregular arteries from the main arcad of the terminal ileal artery are probably collateral channels ; the poorly demonstrated ana recta Operation. Ileal carcinoid close to ileocecal ah with local growth) Hepatic metastases

were hypervascular despite the arterial narrowings. Eight patients had no accumulations. Arteriovenous shunting of medium was never evident. Venous occlusions were present in 11 patients, an observation based on marked venous collateral circulation or occlusion directly visible in the angiograms (Figs 2-4). In only 2 patients was there direct evidence of patent veins. One of these had only slight retraction of the mesentery, and some arterial infiltration (Fig 7).



Fig. 4. Woman with mass in lower abdomen.

a) Marked local widening with absence of normal mucosa polypoid lesion (→) present in terminal ileum. b) Superior mesenteric angiography arterial phase. Distal part of superior mesenteric artery and its branches infiltrated and tortuous with parameters of fibromuscular hyperplasia. Collateral arterial supply from distal jejunal arteries (→) as well as from ileal artery (←) arising from ileocolic artery. S1 flat arrangement. c) Venous phase. Occlusions of veins close to growth. Venous collaterals over right colic veins (→). Operation carcinoma and many small satellite tumours infiltrating the entire lower wall and extending into the mesentery. Malignancy in dilated lymphatics.



primary growth most frequently occurred in the first part of the ileo-colic artery (Figs 2, 3 and 5 to 7). This proximal narrowing was always combined with marked lymph node invasion.

Tortuous arteries representing collaterals were observed in 14 patients. They bore a certain similarity to tumour vessels but neoplastic neovascularity was never defined.

Accumulation of contrast medium within the growth was marked in 3 (Figs 1, 4) and slight in 4 patients. The area of dense accumulation was approximately 5 cm in diameter revealing that the primary growth and the local metastases

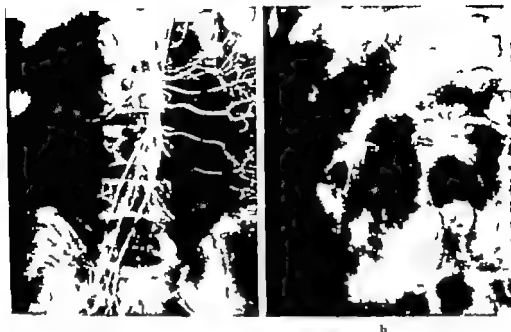


Fig 7 Fine needle biopsy of the liver indicated a carcinoid. a) Superior mesenteric angiography. Dilated colic branch of the ileocolic artery (\rightarrow). Branches of distal part of superior mesenteric artery slightly irregular and displaced by adhesions (\rightarrow). b) Celiac angiography. Richly vascularized large hepatic tumour partly supplied by cystic artery (\rightarrow). Operation. Ileal carcinoid extending through the bowel wall with few lymph node metastases in the ileocaecal mesentery and large lesion in the liver with involvement of the gallbladder.

the other had small arterial wall changes in the vasa recta and the ileal arcades detected first only when the site of the lesion was known even a retrospective angiographic diagnosis was not possible. The small primary tumour had a diameter of 10 mm with a few metastatic nodules in the mesentery. It had however produced massive metastases in the liver (Fig 8).

Hepatic metastases were present in 9 of 12 patients in whom celiac or hepatic angiography was performed. In 7 of these patients there were highly vascularized tumour vessels, were observed in solitary large metastases (Figs 1, 5, 7), dense accumulations of medium were present in nodular metastases of varying sizes (Figs 1, 5, 6). Marked hypervascularization of an enlarged liver and irregular accumulation of medium in the parenchyma were associated when minute metastases were spread throughout the liver (Fig 8). In 2 patients there were not diagnosed at angiography but at operation were reported to be few and small. The 5 HIAA was reported as elevated in 10 patients with hepatic metastases. Neither angiography nor autopsy produced evidence of hepatic metastases despite



Fig. 11. Fine needle biopsy indicated metastases from carcinoid. Hepatic angiography. Enlarged liver with increased vascularization, metastases. Operation: Ileal carcinoid with massive hepatic metastases.

an increase in the 5 HIAA in a patient with widespread metastases in the sternum and retrosternal space

Discussion

MOERTEL *et coll.* (1961) reported that the radiographic diagnosis of an ileal carcinoid by an examination of the small bowel with barium as the only roentgenologic method was difficult because the growth was a small, deep mucosal lesion and any obstruction was intermittent. HUDSON & MAROULES (1964) however, considered in examinations of the small bowel with barium in the 12 patients of their material that the most distinctive feature was the many areas involved. The present investigation would appear to indicate that the abnormalities present in the small bowel to a large extent depend on the stage of the

data. Thus at first when the small tumour is still confined to the wall of the bowel no abnormalities can be expected this is also true where no adhesions or fibroplastic changes are present. With few exceptions the desmoid change in the mesentery appears first when the neoplasm has extended through the serosa and involved the local lymph nodes. Similar alterations in the mesentery with adhesions may be observed in Crohn's disease and are therefore not a definite sign of an ileal carcinoid. Filling defects or malignant constriction in combination with adhesions and concentric arrangement of dilated bowel loops however suggest such a condition. Despite the presence of all these signs the true diagnosis is often made first in retrospect.

An additional observation was the presence of one or two small calcifications in the centre of the desmoid change. Calcification in an ileal carcinoid was recently observed by NOONAN (1971) who considered it was secondary to necrosis of the tumour. ARTHURS & DRURY (1970) however reported elastic vascular sclerosis in 17 of 20 patients with ileal carcinoids that had spread to the mesentery and lymph nodes. This was hidden by mesenteric fibrosis and kinking except in one patient in whom a nodular partly calcified mass was present. The authors pointed out that the massive elastic tissue proliferation was confined mainly to the adventitia of both arteries and veins although it also extended into the mesentery. They had the impression that local spread of the neoplasm into the mesentery was almost invariably associated with elastic sclerosis and also attributed the high affinity of elastic tissue to storage of calcium. Calcification observed in the present material always lay in the centre of the sclerotic process. Because of their situation over the bony pelvis they may have been present more frequently than they were observed. They may be distinguished from lymph node calcifications by their homogeneous density with smooth spherical or ovoid shapes. Phleboliths have the same appearance, but their situation is different and carcinoid calcifications are usually larger.

The most successful method of diagnosis of ileal carcinoids was angiography by which 14 of 15 tumours were demonstrated. Our first report on angiography of 2 carcinoid tumours (REUTER & BILTZ 1966) suggested four signs for both tumours: (1) Sclerotic arterial appearances ought to be caused by retraction of the mesentery by infiltrating neoplasm. (2) narrowing of peripheral mesenteric branch poor to rapid accumulation of contrast medium and (4) no filling of the branches.

The present study confirms that typical changes caused by ileal carcinoids invading the mesentery are: (1) presence of radiating vasa recta and intransmissible shadows (2) narrowing and occlusion of smaller and larger mesenteric arteries (3) REUTER & BILTZ (1966) described a case of sclerosing fibrous peritonitis in which the same radiological appearance was observed. The correct

diagnosis might however have been ileal carcinoid since an operation specimen was not available. The present authors checked the course of this patient: he eventually died but no autopsy was performed.

As mentioned previously a barium examination of the small bowel may reveal changes to suggest Crohn's disease. Adhesions may cause stellate appearances of bowel arteries but narrowing or occlusion of the type observed in carcinoid tumours are absent in regional ileitis.

The present angiographic observations are in agreement with the histologic findings of ANTHONY & DRURY (1970). These indicated that the elastic sclerosis of mainly the adventitia in distant vessels caused marked narrowing and even obliteration of the arteries in patients with mesenteric metastases. The term 'distant vessels' refers to vessels as far as possible from the primary carcinoid tumour in the resected specimen. Angiographically this is comparable with the distal ileal arcade and intramesenteric arteries which always were narrowed or occluded. Stenosis in the more proximal branches of the superior mesenteric arteries such as in the first part of the ileo colic, middle colic, or jejunal arteries was an additional observation in the angiographic series. As already mentioned in the first report these should be regarded as signs of spread of the malignancy along the lymphatics accompanying these vessels.

It is of interest that infiltration of the arteries usually does not mean direct malignant invasion of the vessel wall but rather an extension to the lymph nodes which are blocked. It has been postulated that serotonin may be responsible for the desmoid change. Obviously sclerosis of the vessels occurs first when the regular lymphatic pathways are obstructed. The angiographic findings of pancreatic disease may present a similar explanation.

The arterial stellate appearances may be absent for two reasons. One is that the sclerosis has not markedly changed the mesentery, i.e. local metastases have not developed or are relatively small. A second is that the tumour has infiltrated the mesentery and its vessels to such an extent that the smaller branches are poorly demonstrated by angiography. The arterial infiltration in one patient was so marked and typically situated in the terminal ileum that no differential diagnostic problems arose (Fig. 5). The absence of stellate appearances occurred in 2 further patients who had small lymph node metastases. Both had arterial infiltrations and signs of adhesions with some retraction of the mesentery; in one of these the vascular infiltration was so limited that a definite diagnosis was withheld. There were no other signs indicating the presence of a carcinoid. This means that a small primary carcinoid tumour or its first lymph node metastases will fail to be revealed with our present technique of angiography.

Newly formed neoplastic vessels—often present in other tumours and especially in those of endocrine origin—were not evident in any of the ileal carcinoids. Be-

cause of occlusion in the mesenteric arteries abnormal vessels were usually present but these were regarded as collateral arteries even though some might have represented tumour vessels.

Accumulation of contrast medium within the small primary tumour was never convincingly demonstrated. When present it lay within an area larger than the primary tumour representing local overgrowth to the mesentery. The marked vascular sclerosis with narrowing of both arteries and veins may explain the relatively poor vascularization of the ileal carcinoids.

Venous stenosis or occlusion was a prominent feature and was obviously always present with marked overgrowth of the tumour to the mesentery. Arteriovenous shunting is observed in most neoplasms arising from the bowel as well as in inflammatory disease (Boijssen & Reuter 1966). Our previous report recorded no evidence of shunting in carcinoids, an observation verified in the present series. The main reason for its absence could be the occlusion of the mesenteric veins although it was also not observed in 2 patients in whom the veins were patent.

Venous stasis probably caused the symptoms of sprue or Crohn's disease in this material as well as in other reports. The faecal fat in 2 patients was measured and proved to be elevated. The malabsorption syndrome with steatorrhoea in carcinoid tumour has been reported previously and regarded as secondary to venous occlusion (Kowlessar et al. 1959). In both patients in this material peripheral mesenteric arteries and veins were occluded but not to any greater extent than in other patients without an obvious sprue syndrome although in these the faecal fat was not measured. The importance of examining the mesenteric vascular system in various kinds of malabsorption has been stressed (Boijssen & Tylev 1972). The present authors came upon a carcinoid tumour unexpectedly in one patient with diarrhoea as the only symptom. The absence of early venous filling and occlusion of veins are important diagnostic features in the differentiation of carcinoid tumours from regional enteritis. Acute Crohn's disease always signifies shunting and in an inactive phase there may be even hypovascularity. Even if adhesions and moderate demand changes of the mesentery exist in Crohn's disease arterial wall infiltration would be unlikely.

Other neoplasms of the gastrointestinal tract may cause angiographic changes that should be correlated to those of carcinoids. Reticulum cell sarcoma (Lundquist et al. 1971) and mesenchymal growths (Boijssen & Reuter 1966; Haudt et al. 1972) will not have the angiographic characteristics of carcinoid tumours. Adenocarcinoma and metastases may cause narrowing of mesenteric arteries but probably not the marked demand change observed in carcinoids.

Metastases from alimentary endocrine tumours are richly vascularized as are hepatic metastases from ileal carcinoids. Because of this characteristic quite small

metastases may be observed (LUDRY et coll. 1966). This was confirmed in the present series although it was not demonstrated angiographically in 11 of 7 patients. The metastases in these 2 patients were reported to be small, few in number and located near the surface of the liver. Thus, the metastases appear to possess a higher vascularity than the original growth in the bowel. This is at variance with what has been noted in other neoplasms where the metastases usually have the same type of vascularization as the primary growth. The explanation for this may be the previously mentioned fact that the blood supply of the primary lesion is markedly changed by vascular infiltration.

The present series indicates that hepatic metastases may vary from a few huge nodular masses to small nodules. There is also a third variety of diffuse infiltrating growth. All types have one feature in common: they possess a rich vascular supply that will appear as newly formed tumour vessels if the metastases have reached a certain size. The hypervascularization will otherwise be observed as a dense accumulation of contrast medium. Small nodular metastases in the liver will be revealed only if numerous.

SUMMARY

In a material of 15 patients with ileal carcinoid tumours calcifications were demonstrated in 7 cases. Angiography in 14 of the cases revealed narrowing or occlusion of the superior mesenteric artery. The angiographic diagnosis cannot be made until the ileal carcinoid has extended to the mesentery and infiltrated the lymph nodes. Metastases to the liver are always richly vascularized and were present in 7 of 9 patients.

ZUSAMMENFASSUNG

In einem Material von 15 Patienten mit am Ileum ausgehenden karzinoiden Tumoren wurden 7 Fälle mit Kalkifikationen beobachtet. Die Angiographie ergab in 14 dieser Fälle eine Verengung oder einen Verschluss der Arteria mesenterica superior. Die angiographische Diagnose kann nicht gestellt werden bevor das Carcinoid das Mesenterium erreicht und die Lymphknoten infiltriert hat. Lebermetastasen sind stets reichlich vaskularisiert und fanden sich bei 7 von 9 Patienten.

RÉSUMÉ

Sur une série de 15 malades atteints de tumeurs carcinoides d'intestin grêle les auteurs ont observé des calcifications dans 7 cas. L'angiographie chez 14 malades a toujours montré un rétrécissement ou une obstruction de l'artere mésentérique supérieure. Le diagnostic angiographique ne peut être fait avant que le carcinome d'intestin grêle se soit étendu au mésentère et ait infiltré les ganglions lymphatiques. Les métastases hépatiques sont toujours richement vascularisées et existaient chez 7 malades sur 9.

REFERENCES

- ANDERSEN J B, MADSEN B and SØJOLDSBORG H. Angiography in a case of carcinoid tumor in the stomach. *Brit J Radiol* 44 (1971) 218.
- ANTHONY P P and DILLON R A II. Elastic vascular scleroses of mesenteric blood vessels in argentaffin carcinoma. *J clin Path* 23 (1970) 110.
- BUTTI I. Gastrointestinal carcinoid tumors. *Radiology* 74 (1960) 573.
- BORJES E. Superior mesenteric angiography. *J Angiography* Vol II p 1091. Edited by H L Abrams. Little Brown & Co. Boston Mass 1971.
- and REUTER B. Mesenteric angiography in the evaluation of inflammatory and neoplastic disease of the intestine. *Radiology* 87 (1966) 1028.
- and TYLÉN U. Abnormalities of the superior mesenteric artery in idiopathic sprue. 9th Int Congr Gastroenterology, Paris 1972 p 435.
- CLAPS R J, LAYDE A, LILKENFIELD R and NILEA M. Angiographic demonstration of an ileal carcinoid. *Radiology* 103 (1972) 87.
- DARLE N. Carcinoid magntarmkanalen (I Swedish). *Läkartidningen* 69 (1972) 1491.
- DARLING G C and WELSH C E. Tumors of the small intestine. *New Engl J Med* 260 (1959) 397.
- GOLD R E and REDMAN H C. Mesenteric fibrosis simulating the angiographic appearance of ileal carcinoid tumor. *Radiology* 103 (1972) 85.
- GOOD C A. Tumors of the small intestine. *Amer J Roentgenol* 89 (1963) 683.
- HOBLEY B L and BAKER R R. Fibroplastic response to intestinal carcinoid. *Amer Surg* 36 (1970) 676.
- HUDSON H L and MAROULIS A R. The roentgen findings of carcinoid tumors of the gastrointestinal tract. *Amer J Roentgenol* 91 (1964) 833.
- KALDE J, SLETTEN G and TYLÉN U. Angiography in myomas of the gastrointestinal tract. *Acta radiol* Diagnosis 12 (1972) 691.
- KOWLEBAR O D, LAW D H and SLETTEN U M III. Malabsorption syndrome associated with metastatic carcinoid tumor. *Amer J Med* 7 (1959) 673.
- LUDVIG H, FÄSTERLANDER H J and REINOLDI I. Zur Darstellung von Karzinoid Lebermetastasen mittels visceraler Arteriographie. *Schweiz med Wochr* 96 (1966) 1642.
- LI DERQIST A, LI DERQIST A, HOLMQUIST K III and CLEMENS F. Selective superior mesenteric arteriography in reticulum-cell sarcoma of the small bowel. *Radiology* 98 (1971) 113.
- MACDONALD R A. A study of 336 carcinoids of the gastrointestinal tract. Report of four new cases of the carcinoid syndrome. *Amer J Med* 21 (1956) 867.
- MARSHALL R H and LINDNER A E. *Radiology of the small intestine*. W B Saunders Company Philadelphia 1970.
- MILLER E R and HERRMANN W W. Argentaffin tumors of the small bowel. A roentgen sign of malignant change. *Radiology* 39 (1942) 214.
- MOOREL C G, DOCKERTY M D and JUDS S. Carcinoid tumors of the vermiform appendix. *Cancer* 21 (1968) 270.
- , SALKER W G, DOCKERTY M B and BARNHARTER H H. Life history of the carcinoid tumor of the small intestine. *Cancer* 14 (1961) 901.
- NATIONAL BOARD OF HEALTH and WELFARE. Cancer Registry. Cancer Incidence in Sweden 1959—1965. Göteborgs Offsettryckeri AB Stockholm 1972.
- NEERHAR R A, POLLARD J J and STUCKE D L. Angiographic diagnosis of malignant disease of the liver. *Radiology* 86 (1966) 284.
- NOVAK C D. Calcified carcinoid of small bowel. *Radiol clin biol* 41 (1971) 115.

- REUTER S. H. and BOIJSE E.: Angiographic findings in two ileal carcinoid tumors. *Radiology* 87 (1966) 836
- SANDERS R. J. and AXTELL H. N.: Carcinoids of the gastrointestinal tract. *Surg. Gynec. Obstet.* 119 (1964) 369
- SIMONIN P. M., DE VITA V. T. and DOPPMAN J. L.: Arteriography of an ileal carcinoid tumor. *J. Canad. Ass. Radiol.* 22 (1971) 259
- SIMPSON A. J.: The carcinoid tumor syndrome and spectrum. *N. Engl. J.* 30 (1969) 399 and 452
- STARK S., BLUTH I. and RUBINSTEIN S.: Carcinoid tumor of the ileum resembling regional ileitis clinically and roentgenologically. *Gastroenterology* 40 (1961) 813
- TIMORSON A., BJORK G., BJORKMA G. and WALDENSTROM J.: Malignant carcinoid of the small intestine with metastases to the liver (alveolar disease of the right side of the heart, pulmonary stenosis and tricuspid regurgitation without septal defects), peripheral vasomotor symptoms, bronchobronchoconstriction and an unusual type of cyanosis. A clinical and pathologic syndrome. *Amer. Heart J.* 47 (1954) 79
- WOOD W. J., ARCHER R., SCHAEFFER J. W., STEPHENS C. and GRIFFE JR W. O.: Coexistence of regional enteritis and carcinoid tumor. *Gastroenterology* 39 (1960) 265

ORGANIC TRICUSPID VALVULAR INSUFFICIENCY IN CHILDREN

J. T. MALLAMO and E. CARLSSON

Clinically significant organic tricuspid valvular disease unrelated to other cardiovascular abnormalities is rare (GLANCY et coll 1969) and its many causes include congenital anomalies, carcinoma, heart disease, trauma, endomyocardial fibrosis of the right ventricle and infective endocarditis (ARY & SEGAL 1966, CHERUBIN et coll 1968, GLANCY et coll 1969, OSBORN et coll 1964). The functional form of tricuspid insufficiency, supposedly related to hypertrophy and later dilatation of the right ventricle with subsequent dilatation of the tricuspid annulus, is uncommon when the heart is in sinus rhythm. No cases of rheumatic heart disease involving only the tricuspid valve with or without insufficiency have been reported.

The most common causes of congenital tricuspid insufficiency are defects in the valve associated with Ebstein's malformation and an endocardial cushion defect with or without the latter (KING et coll 1962); a less common reason is congenital incompetence due to diseases that prevent closures of the apparently normal tricuspid valve. Fenestration of the tricuspid valve, this is uncommon, is variably associated with an atricular septal defect and has not otherwise been reported.

Traumatic tricuspid insufficiency falls into two categories (1) ruptured papillary muscle and (2) ruptured chordae tendinae with or without the valve (MORGAN & FORKNER 1971). Although most of these lesions are a result of mechanical injury and myocardial infarction some have been reported to occur secondarily to syphilis, myocardial abscesses and polyarteritis nodosa (OSBORN *et coll.* 1964). Symptoms and signs are frequently absent or mild and the onset may be delayed especially in group 2. If the papillary muscles are ruptured the symptoms and signs are more acute (MORGAN & FORKNER 1971).

Isolated right sided vegetations were evident at autopsy in about 5 per cent of cases with infective endocarditis (BAIN *et coll.* 1958; SHANKAR *et coll.* 1967; WILSON 1963). Most of these had no underlying heart disease the vegetations appearing on previously normal valves (GLANCY *et coll.* 1969). Bacterial and mycotic endocarditis is a serious complication in drug addiction (CHERUBIN *et coll.* 1968). CHERUBIN *et coll.* reported sole tricuspid valve changes in 9 per cent and bilateral multivalvular endocarditis involving the tricuspid valve in another 9 per cent of such cases. As expected, the aortic and mitral valves were those most commonly affected (CHERUBIN *et coll.* 1968). *Staphylococcus* was the major organism isolated in CHERUBIN's series of drug addicts admitted to hospital.

Right sided differs from left sided endocarditis in many respects. Septic pulmonary emboli, pneumonitis and abscesses are characteristic of tricuspid valve endocarditis. Systemic arterial emboli and various forms of glomerulonephritis which are more common with left sided valvulitis, however occur with isolated tricuspid lesions. With the exception of abscesses and pyelonephritis, renal lesions are rarely associated with right sided endocarditis. Protein losing enteropathy has also been linked with tricuspid insufficiency (STROBER *et coll.* 1968).

The purpose of this communication is to report 2 rare cases of organic tricuspid valve insufficiency in small children (CHERUBIN *et coll.* 1968) in one of which the degree of regurgitation was measured with the cineradiographic methods available. In one of the cases the posterior tricuspid valve leaflet was fenestrated in combination with valvular and infundibular pulmonary stenosis while in the other the tricuspid valvular insufficiency (caused by staphylococcal valvulitis) was isolated.

Case reports

Case 1 Female, a Caucasian, aged 34 months was born at 8 months weight 2.5 kg. No reports of serious illness or family history of congenital heart disease. A cardiac murmur was present. She did well until 2 years of age when progressing erythematous brought her to the hospital. Her development appeared satisfactory except for a 50 per cent reduction in exercise tolerance. At 30 months she could rest without squatting when fatigued. ECG: Right bundle branch block and right ventricular hypertrophy. Chest roentgenography



Fig 1 Ca 1 Chest p. Significant enlarged right atrium and right ventricle small middle pulmonary artery with decreased pulmonary vascularity

Marked cardiac enlargement with reduced pulmonary vascularity. No neck vein distension evident per beat in the 5th intercostal space at the left midclavicular line. A moderate systolic thrill was present over the left border of the sternum with a ventricular thrust to the right of the xiphoid process. A grade 4/6 harsh systolic murmur was heard over the lower left border of the sternum and grade 3/6 blowing systolic murmur was present at the second left intercostal space associated with a grade 2/6 systolic murmur. The liver was palpable 2 cm below the right costal margin. Moderate cyanosis of the finger and toe nails with purplish discoloration of the tips. The digits without clubbing was noted. At 34 months single chest film (Fig 1) revealed an enlarged right atrium and right ventricle and a small main pulmonary artery with decreased pulmonary vascularity. At cardiac catheterization a moderate right to left shunt at the atrial level was present although the mean pressures were equalized indicating large communication between the atria. Right atricular and ductal pressures were not elevated and the right atricular systolic pressure (110/7) was about 20 mm Hg higher than that of the left ventricle (90/7) with triangular configuration representing an intact atricular septum. The pulmonary and systemic vascular resistances were normal. Cine angiography demonstrated that the right ventricle was hypertrophied with a large amount of contrast medium extravasating into and filling the dilated right atrium (Fig 2). A systolic jet (Fig 3) suggested a defect in the right leaflet of the tricuspid valve. The right atricular outflow was dilated and restricted (Fig 4). The thickened pulmonary valve was dome shaped in the main pulmonary artery, as dilated. Cardioangiography suggested bilateral pulmonary stenosis and tricuspid insufficiency. Operation revealed dilated right atrium with atrial appendage and a large right ventricle. The coronary arteries were normal. There was harsh thrill over the main pulmonary artery. The dome shaped pulmonary valve measured 2 mm in diameter. Longitudinal coronary arteriotomy with an incision in the pulmonary artery completed the resection. A regurgitant jet from the tricuspid valve was palpable in the right



Fig. 2



Fig. 3

Fig. 2 Case 1. Cineangiogram. Right ventricle enlarged and hypertrophied enlarged right atrium.

Fig. 3 Case 1. The contrast medium has regurgitated from the right ventricle to the right atrium (→) during entricular systole indicating defect in the lateral leaflet of the tricuspid valve (confirmed by operation).

trium during entricular systole. A rounded fenestration 1 cm in diameter noted in the small lateral leaflet of the tricuspid valve as well as a patent foramen ovale were closed. On completion of the operation the tricuspid valve was competent. The pressures in the right side of the heart were: right atrium 6 mm, right entricular body 42 mm systolic, right entricular infundibulum 35 mm and main pulmonary artery 25 mm systolic. The post-operative course was uneventful and the patient was discharged without medication.

Case 2. Male Caucasian aged 42 months, normal pregnancy with a weight at birth of 3.6 kg. The neonatal period and early infancy were also normal with no history of cyanosis, cardiac murmur, respiratory difficulty or family heart disease. The child was well until he was 30 months of age when he was ill with a short history of temperature of up to 40°C. Blood culture: *Staphylococcus aureus* coagulase positive. A mild postular rash was treated with penicillin 6 million units intravenously. *Staphylococcus pneumoniae* developed and progressed to bilateral empyema requiring multiple thoracenteses and chest tubes. An initial chest film at 30 months had been normal (Fig. 4a). He subsequently developed congestive heart failure with progressive cardiomegaly. Treatment with digitalis was commenced. ECG: T wave inversion which reverted to normal after 2 weeks. A heart murmur the character of which was not described was first noted along with gallop rhythm. The patient was discharged on digitalis after 6 weeks of intravenous antibiotics. Roentgenography of the chest at 38 months recorded significant cardiac enlargement with a prominent right atrium but no pulmonary oedema (Fig. 4b).

When the patient was 43 months old he was admitted to the University of California, San Francisco for cardiac catheterization. A neck vein distension evident. Bilateral prominent pulsations were noted in the supraclavicular areas. A diffuse left parasternal impulse was thought to represent the right entricular impulse, no left entricular impulse



Fig 4 a) Case 2 Chest x-ray Normal with no cardiac enlargement or signs of congestive heart failure b) Eight months later. Signifies cardiac enlargement with prominent right atrium but no evidence of pulmonary oedema

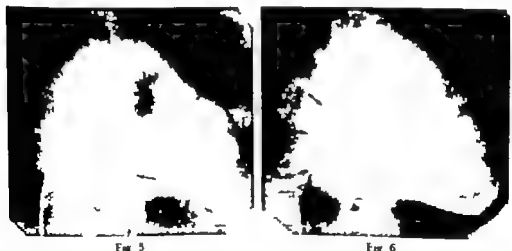


Fig 5 Case 2 Cineangiogram. Tricuspid regurgitation normal in position. Tricuspid contrast medium filled the large trabeculated right atrium. No contrast regurgitated to the enlarged right atrium.
Fig 6 Case 2 Ventricular diastole. Tricuspid regurgitation. Contrast medium of right ventricular enlargement is indicated by arrow.

present. A prominent thrill was noted along the lower left border of the sternum. The heart sound was muffled. There was a grade 2/6 murmur of S1 and S2 with the aortic and pulmonary component of equal intensity but not synchronous with respiration. No S3 was evident. A grade 3/6 somewhat harsh long systolic murmur of plateaus shape was best heard along the lower left border of the sternum radiating to the right axilla. A grade 2/6 midsystolic murmur



Fig 7



Fig 8

Fig 7 Case 2 The left ventricle in diastole small compared to the enlarged right ventricle

Fig 8 Case 2 The small left ventricle displaced posteriorly by the enlarged right ventricle

was present at the upper right and left borders of the sternum and radiating along the pulmonary outflow tract with grade 1/6 early diastolic rumble on the left side. The liver was palpable 2 cm below the right costal margin; no clubbing or cyanosis present. ECG: Right bundle branch block. Cardiomegaly with prominent right atrium but without signs of congestive heart failure in a conventional chest film.

Cardiac catheterization enabled the blood oxygen saturations to be compared; these were normal in all chambers indicating no left-right shunt at any level. The ascending aortic oxygen saturation and tension were normal, eliminating a right-to-left shunt. Pulmonary and systemic flows were equal and normal. The mean pressure in the right atrium and superior and inferior vena cava was slightly elevated with a dominant V wave compatible with tricuspid insufficiency. The right atrial pressure was sometimes normal but a dominant V wave was invariably present. The right ventricular pressure was at its upper normal limits with slightly elevated end diastolic pressure (32/9). The mean and phasic pressures of the main pulmonary artery were also normal; the left ventricular pressure was not affected. An electrocathode placed in the body of the right ventricle with simultaneous pressures and intracardiac ECG measurements ruled out Ebstein anomaly. Cineangiography revealed the tricuspid valve to be in normal position with a large trabeculated right ventricle and filling of a dilated right ventricular outflow tract and a large right atrium during ventricular systole (Fig 5). The right ventricle was markedly enlarged in diastole (Fig 6). The pulmonary valve was competent. The left compared to the right ventricle was small (Fig 7) and displaced posteriorly by the enlarged right ventricle (Fig 8). Ventricular volume measurements were obtained from the right and left ventricular cineangiogram (Table).

Table
Ventricular volume measurement

	Right ventricle	Left ventricle
End-diastolic volume	51.3 ml/m	15.3 ml/m
End-systolic volume	21.6 ml/m	4.4 ml/m
Stroke volume	36 ml/m	10.9 ml/m
Right ventricular stroke volume	= 3.3	
Left ventricular stroke volume	= 3.3 ml/beat	
Tricuspid regurgitant flow		

Cardiography indicated tricuspid aly insufficiency. The hospital course was uneventful; the patient was discharged and since then has remained in congenital heart failure.

Comments

The diagnosis of tricuspid insufficiency may at times present difficulties especially in children. The typical signs of the lesion i.e. positive systolic pulsations of the neck veins, pansystolic murmur frequently accentuated on deep inspiration, cyanosis and hepatomegaly usually although not always indicate gross insufficiency. Less severe regurgitation may be present without the usual signs of the condition (ARON & SEGAL 1966).

The characteristic pansystolic murmur may not be audible even in patients with gross regurgitation and large V waves in the neck. The clinical course of right-sided heart failure usually is slowly deteriorating. Although this may be true for many adults with slight or moderate tricuspid insufficiency, sudden death is more common especially in children with gross lesions (ARON & SEGAL 1966; KELLER et al. 1970). ARON stated that the overall prognosis in isolated tricuspid valve insufficiency is as much worse than previously believed with 16.5 years as the average survival age of patients with congenital tricuspid insufficiency. Although the diagnosis of tricuspid valve insufficiency may be made at cardiac catheterization by means of indicator dilution and right atrial pressure curves, false positive indicate the need for right ventricular cardiography.

Cardiography will also permit quantitation of the degree of tricuspid valve regurgitation with the method described for right and left ventricular volume measurements by GOERKE et al. (1967) and CARLSSON et al. (1971). The difference in stroke volume between the right and the left ventricles constitute the regurgitant flow per heart beat. This approach is valid as long

as there is no shunt or additional valvular insufficiency of the right ventricle. The ventricular septum in Case 2 was intact at cardiac catheterization and cardioangiography. No signs existed of pulmonary valve insufficiency. However a separate injection of contrast medium into the main pulmonary artery to rule out this possibility was not made. The injection of medium into the right ventricle caused ectopic beats so that the stroke volumes measured on the right and the left sides were not directly comparable. It has been demonstrated earlier that temporary volume discrepancies between the two ventricles may be allowed for if the effective diastolic filling time of the two beats be calculated from the films and the ratio between the two time periods be presumed to be one in the disturbed heart. Accurate stroke volume comparisons in a group of patients with no shunts or valvular insufficiencies were obtained by this method (CARLSSON *et coll* 1971). It is possible that the diastolic filling time ratio is different with large variations in stroke volume between the two ventricles. The largest ventricle would then be expected to have the longest filling time presumably accomplished by a reduction in the length of the diastasis. If a difference in filling time indeed exists with a longer time for the largest ventricle this would tend to increase the difference calculated in stroke volumes. The measurements now presented would therefore indicate a minimum difference and if anything, an underestimation of the degree of tricuspid valve insufficiency. Even without actual measurement cardioangiography will allow a semiquantitative estimate by observation alone. Quantitation should always be attempted in children as the degree of regurgitation may vary considerably and because the severe forms are associated with a high mortality rate (AUB & SEQAL 1966).

Some authors (CARNS *et coll* 1968 GOULD *et coll* 1965 PARKER *et coll* 1967) have concluded that contrast medium regurgitation is usually absent with atrial fibrillation but may be induced by catheter interference with the tricuspid valve. BOGREN *et coll* have reported that the tricuspid valve closure is not impaired by the presence of the catheter per se in the tricuspid orium with normal sinus rhythm. If extrasystoles be produced by the injection of medium the resultant valve insufficiency may usually be identified as accidental (BOGREN *et coll* 1972).

The ventricular volume measurements in Case 2 indicate a marked degree of tricuspid valvular regurgitation (approximately 23 ml per heart beat with a stroke volume of 36.2 ml see Table). The ejection fractions of the ventricles are equal and within normal limits. The left ventricular volume is considerably smaller than the normal value for a 3.5 year old child indicating interference with the diastolic filling by the enlarged right ventricle. GRAHAM *et coll* stated that the normal value of the left ventricular enddiastolic volume is 17 ± 2 ml/m² body surface area in children over 2 years of age (GRAHAM *et coll* 1971) while

such volume in children under 2 years is 42 ± 1 ml/m. These authors suggested that the discrepancy is probably caused by a difference in heart rate. The group of patients over 2 years had an average heart rate of 99 ± 15 while the average mean rate of those under this was 142 ± 14 . The heart rate of the present patients was 120 immediately before and during the cardioangiography. A left ventricular end diastolic volume of 15.3 ml is still much below normal. GRAHAM however stated in a later report (1972) GRAHAM et coll. (1972) that patients with a large right ventricle may have a reduction of as much as 50 per cent in the left ventricular end diastolic volume which would mean approximately 20 ml. In view of this the volume figure now given would appear reasonable.

Acknowledgements

This work was supported in part by USPHS Training Grant No. HL-00874

SUMMARY

Two cases of organic tricuspid valve insufficiency in children are reported. The significance of quantitation is stressed and a cinematographic method for measurement of the regurgitant flow applied in one of the cases is described and discussed.

ZUSAMMENFASSUNG

Zwei Fälle einer organischen Trikuspidalklappeninsuffizienz bei Kindern werden beschrieben. Die Bedeutung der quantitativen Beurteilung wird hervorgehoben und eine Serien-röntgen Methode zur Messung des Rückflusses wie sie bei einem der Fälle angewendet wurde beschrieben und diskutiert.

RÉSUMÉ

Présentation de deux cas d'insuffisance organique de la valvule tricuspidale chez des enfants. Les auteurs insistent sur l'importance d'une évaluation quantitative et décrivent et discutent une méthode cinématographique pour la mesure du débit de régurgitation.

REFERENCES

- | | |
|--|---|
| ANN, A. J. and WALSH, P. T. (1966) Tricuspid insufficiency. Clinical features, diagnosis and management. <i>Proc. Roy. Soc. Med.</i> 59 (1966) 168. | 1 tricuspid insufficiency. Clinical features, diagnosis and management. <i>Proc. Roy. Soc. Med.</i> 59 (1966) 168. |
| BARN, R. C. EDWARDS, J. and GIBSON, J. E. (1968) Right-sided bacterial endocarditis and tricuspid insufficiency. <i>Am. J. Pathol.</i> 74 (1968) 98. | 2 C. H. and GIBSON, J. E. Right-sided bacterial endocarditis and tricuspid insufficiency. <i>Am. J. Pathol.</i> 74 (1968) 98. |
| BOGREN, H. E. (1972) Pulmonary insufficiency by cineangiography. <i>Acta Pathol. Microbiol. Scand.</i> 75 (1972) 147. | 3 BOGREN, H. E. (1972) Pulmonary insufficiency by cineangiography. <i>Acta Pathol. Microbiol. Scand.</i> 75 (1972) 147. |
| GRAHAM, J. M. H. and GRAHAM, J. M. H. (1972) Right-sided heart failure. <i>Br. Med. J.</i> 3 (1972) 497. | 4 GRAHAM, J. M. H. and GRAHAM, J. M. H. (1972) Right-sided heart failure. <i>Br. Med. J.</i> 3 (1972) 497. |

- CARRA H. B. KLOTTER F. E. BRISTON J. D. et coll. Problems in the hemodynamic diagnosis of tricuspid insufficiency. *Amer Heart J* 75 (1968) 173
- CARLSON E. KEENE T. J. LEE P. and GOERKE R. J. Angiocardiographic stroke volume correlation of the two cardiac ventricles in man. *Invest Radiol* 11 (1971) 44
- CERRUBIN C. E. BADEN M. et coll. Infective endocarditis in narcotic addicts. *Ann intern Med* 70 (1968) 1091
- GLANCY D. MARCELA F. I. CUADRA M. et coll. Isolated organic tricuspid valvular regurgitation. *Amer J Med* 46 (1969) 969
- GOERKE R. J. and CARLSON E. Calculation of right and left cardiac ventricular volumes. Methods using standard computer equipment and biplane angiocardiograms. *Invest Radiol* (1967) 360
- GOULD L. WEFER D. SCHAEFER A. I. and O'CONNOR R. A. Does atrial fibrillation lead to tricuspid insufficiency. *Amer J Cardiol* 16 (1965) 189
- GRAHAM T. P. JR. JARMALANYI J. M. and CANENT R. JR. Left ventricular volume characteristics with a right ventricular volume overload. *Circulation* 45 (1972) 389
- — — and MORROW M. V. Left heart volume estimation in infancy and childhood. *Circulation* 43 (1971) 895
- KELLER B. D. BOAL B. H. LEWIN A. and KALTHAN A. J. Development of tricuspid aortic regurgitation during course of chronic cor pulmonale. *Chest Dis Index* 57 (1970) 196
- KINGARD O. W. SWAN H. J. O'NEILY P. A. and TITUS J. L. Congenital tricuspid insufficiency. Report of two cases. *Proc Mayo Clin* 37 (1962) 640
- MORGAN J. R. and FORKER A. D. Isolated tricuspid insufficiency. *Circulation* 43 (1971) 359
- OSBOR J. R. JONES R. C. JAFFER E. K. JR. Traumatic tricuspid insufficiency. Hemodynamic data and surgical treatment. *Circulation* 30 (1964) 217
- PARKER B. M. FAIRBANKS M. J. SMITH R. M. and HUDSON H. L. Angiographic evaluation of regurgitation through normal tricuspid and mitral valves of dogs. *Radiology* 79 (1967) 296
- SAPINDERY W. and BAKER C. B. Isolated tricuspid valve stenosis. Report of a surgically treated case. *New Engl J Med* 269 (1963) 236
- SHANLEY A. R. HULTOREN M. K. LAUER R. M. et coll. Lethal tricuspid and mitral regurgitation in Marfan's syndrome. *Amer J Cardiol* 20 (1967) 122
- STROKER W. COHEN L. S. WALDMANN T. A. and BRAUNWALD E. Tricuspid regurgitation. A newly recognized cause of protein losing enteropathy, lymphocytopenia and immunologic deficiency. *Amer J Med* 44 (1968) 842
- WILSON L. M. Etiology of bacterial endocarditis before and since the introduction of antibiotics. *Ann intern Med* 58 (1963) 946

FILM QUALITY IN MAMMARY RADIOGRAPHY

E DEICHGRABER S REICHMANN and M BUREN

Reference to the literature for some help as to the best film for roentgenography of the female breast soon discloses that almost every type of film has its advocate EGAN (1964) and EGAN & FEENEY (1968) recommended low sensitivity industrial non screen films which was also approved by MENAGI et coll (1968) and YOUNG (1969). At the other end of the sensitivity spectrum lies the technique described by STRAX & OPPENHEIM (1968) with an image intensifier and a 70 mm camera. GERSHON COHEN et coll (1965) pioneers of mammary radiography had for long stubbornly criticized the use of low sensitivity industrial film implying that this had a relatively poor rendering of contrast as compared with the usual medical non screen film. Furthermore they considered the dose to the patient to be too high. However when they replaced the tungsten target roentgen tube with one with a molybdenum target, which gives higher doses owing to soft radiation (KRAUSE & REISS 1968) they suddenly came to recommend the fast type A industrial film accepting a dose increase from about 1 rad/exposure to about 2 rad/exposure (GERSHON COHEN et coll 1970). The choice of film was left unexplained. High sensitivity industrial film was recommended by PRICE & BUTLER (1969) and REICHMANN (1969) with the same reasoning they did not compress the breast could not use films of low sensitivity.

Submitted for publication 22 January 1973

Most authors agree that non screen film appears to be best for mammary radiography. One problem with this type of film exists however namely the achievement of proper processing. Such film contains much more silver than ordinary roentgen film by reason of the thicker emulsion. This requires more time for the diffusion of the processing chemicals, the fixing and the rinsing are especially difficult, tending to make long process times necessary (LUNDH 1972). Industrial film contains large amounts of silver and consequently the process time is also relatively long, so far optimal development of such film has been achieved only by means of tank processing. This has been a serious drawback and has given rise to attempts at using film adapted for shorter processing. Thus a non screen film has recently been introduced for radiography of the breast and processing in 90 seconds. This film was tested and approved by BARTH *et coll.* (1972). Likewise a Medichrome film (Agfa Gevaert) intended for intensifying screens has been used without screens by FLOAZZOLA (1971). This film too was regarded as being of superior quality. However if a non screen film contains only submaximal amounts of the recording medium i.e. silver it may also be expected to afford only submaximal information. Thus if the silver content be low so as to make the film processing easy, then the image quality may also be down.

Progress has lately been made in the composition of processing reagents. Thus a new combination of chemicals has made possible a processing time of 6 minutes for industrial non screen film in an ordinary roll machine.

The present investigation was aimed at the image quality obtainable with a 90 second film for examining the breast in comparison with an industrial film of equal sensitivity, the latter being processed in 6 minutes. Consideration was also given to whether tank development will increase image quality in either of the two film types. Furthermore an attempt was made to establish the optimal sensitivity of the film type considered preferable.

An emulsion with a high silver content—Agfa Gevaert Mamoray 2—was compared with an emulsion for 90-second processing Kodak PE 4006 in order to decide which type of emulsion and development would produce most information for a given dose of radiation. Since the emulsion with a high silver content gave better recordings such emulsions of varying sensitivity were compared. The investigation was carried out in several steps, each based on the earlier results. Each test together with its results will now be described before the next is presented.

The characteristic curves of the two types of emulsion when developed in a machine and a tank were examined. The chemicals in all types of processing are presented in Table 1, the temperature was in accordance with the recommendations of the manufacturer. The Mamoray film was machine developed with

Table 1

*Survey of the different kinds of processing of the L10 films test d. All chemicals manufactured by Agf
Cristal*

Film	Tank process	6 min roll machine	90 sec roll machine
PE 4006	dev G 150		dev G 138
	fix G 334		fix G 334
Mammary 2	dev G 150	dev G 192	
	fix G 334	fix G 392	

a processing time of 6 minutes, this length of time being necessary for proper fixing and rinsing. The roll machine used in this test as well as in the 90 second processing was a Pakorol. The films were exposed in a stepwise manner so that the characteristic curves could be obtained after being subjected to densitometry. The following results emerged. Both films underwent a slight decrease in sensitivity when developed in a roll machine as compared with optimal tank development. The form of the characteristic curve did not change appreciably. When the shapes of the curves for the two film types were compared one important difference was evident. The Mammary film had a curve displaying increasing inclination up to density $D=3$ (the highest value of the densitometer) while the curve of the other film began to decrease in inclination at $D=2.5$. This was interpreted as an indication of a lower silver content in the second emulsion than in the first. When the absolute sensitivities of the two films were compared it became apparent that the PE 4006 emulsion had a slightly lower sensitivity.

As a difference in the shape of the characteristic curves of the two films existed above $D=2.5$ an attempt was made to discover the optimal density level for roentgenography of the breast. Slices of breast tissue were exposed in a Siemens Mammomat equipped with a molybdenum target and filter at a tube potential of 28 kV. Different mAs settings were used so that varying densities were obtained in the Mammary 2 film which was developed in a roll machine as described above. A background density of $D=2.0$ proved most suitable. Higher densities caused trouble in inspection even if strong light was used whereas lower densities made for less image contrast. It thus appeared that roentgenography of the breast should preferably be performed at a density level at which the two films display similar characteristic curves. The quality of the film is only partially indicated however by the characteristic curve. Grain mottle is also important. This factor reflects how many of the photo-



Fig. 1. The same magnification of areas of identical density in (a) the 90 second film and (b) the industrial film. The graininess is decreased in (b).

the film are really absorbed so that their effect is incorporated into the final image. Most photons are not absorbed although different films may take up differently large fractions of a given roentgen dose thus displaying varying degrees of efficiency. A film of high efficiency makes for low quantum mottle and will have a higher resolving power than one with the same sensitivity but lower efficiency.

The efficiency of a film or a screen film combination depends on the fraction of photons absorbed from the incident radiation. This absorptive capacity is determined with non screen film by the silver content. Thus, emulsions with a high silver content generally produce images with a lower quantum mottle than those of lower silver content while yet of the same sensitivity.

The two emulsions compared in the present investigation were found to possess roughly the same sensitivity but a difference in the characteristic curves of the films indicated a lower silver content in the 90 second emulsion. The next task was to assess whether any difference existed in quantum mottle in comparable images of the two films. The first approach to this problem was based on photomicrography of areas of the same density in the two films. It appeared that the grain in the 90 second film was coarser (Fig. 1). This is in accordance with the assumption of a difference in silver content and quantum mottle. If fewer photons be assumed to produce a given density then each silver grain precipitated must be larger since each photon can give rise only to one silver grain.

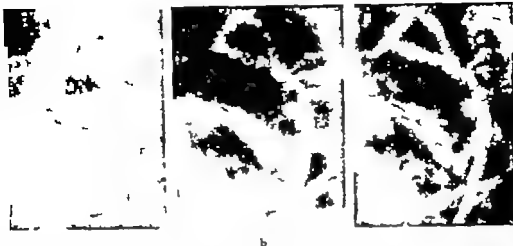


Fig. 2 The same detail from a) a 90-second film and b) an industrial film with high silver content. The copy in c) is obtained after exact superpositioning of the films in (a) and (b). A marked difference in information is evident. Magnification $\times 2$.

(BAGASTROM & LUNDH 1959). Now the question arises whether the differences demonstrated in quantum mottle are of any importance. The only answer to this problem must be based on clinical roentgen examinations of mammae. To obtain completely comparable images the two films were placed in one envelope with the somewhat less sensitive 90-second film nearest to the roentgen tube; the absorption of this film produced the same density in the two films in spite of the differences in sensitivity. All exposures were made with the Mammomat and the films developed in roll machines as described. A total of 22 pairs of roentgenograms were examined in this way with uniform results. Inspected at a distance the pair seemed to be identical. At high densities however such as in the periphery of the breast image the blackening was lower in the 90-second film owing to the difference in the characteristic curves. On closer scrutiny even without magnification this film appeared to possess less contrast even in the central area of the breast, not obvious in the ordinary way. Detail of low contrast was thus much more apparent in the film with a high silver content (Fig. 2 a, b). Likewise microcalcifications were more readily recognized in such. The 90-second film often left doubt whether small points were calcifications or not. There was no apparent difference in unsharpness.

Having established that only emulsions with a high silver content are worth testing in roentgenography of the breast the question of the optimal degree of sensitivity had to be examined. It was assumed that only a small difference exists



Fig. 3. The same detail of a breast phantom recorded in industrial film of high silver content with different sensitivities. Three nylon threads (diameters 1.0, 0.75, and 0.5 mm) are situated in a layer of vegetable oil (height 3 cm). The film sensitivities (cf Table I): a) 100; b) 170; c) 325; d) 325; e) 650. The image quality rapidly deteriorates when the sensitivity rises from 100 to 170.

between non-screen films of identical sensitivity offered by different manufacturers as long as these possess a high silver content: one gram is of course always obtained from one absorbed photon. A series of films of high silver content and a relative sensitivity ranging from 25 to 650 was tested; it being assumed that the sensitivity of Mamoray 2 is 100. These films enabled roentgenograms of similar density of breast phantoms to be made at two tube potentials of the Mammomat: i.e. 28 and 35 kV. The phantoms were similarly constructed but represented different masses of soft tissue. They consisted of quadrangular thin-walled plastic bottles more or less filled with vegetable oil in which were nylon threads of 0.25 mm to 1 mm diameter. Minute calcifications were embedded in epoxy resin within the bottles. The thickness of the oil layer amounted to 1 cm, 3 cm, 5 cm, and 7 cm; the bases of the bottles measured 9 cm \times 15 cm. All films were tank developed since those of the highest sensitivity proved to be extremely sensitive to the pressure exerted by the rolls of the developing machine.

The results of this investigation were uniform (Fig. 3). The quantum mottle at sensitivity 100 and below could not be discerned without a magnifying glass. The reproduction thus appeared to be smooth and grain-free. With the naked eye no difference in information capacity was evident between sensitivities of 100 and 25; magnification revealed differences however so that sensitivity 25 gave a higher resolution to make lower contrast visible. With a film sensitivity over 100 the quantum mottle became increasingly apparent to the naked eye. The most disturbing increase occurred between sensitivities 325 and 650. In passing from

Tabl 2

Survey of different films used in comparison between different sensitivities in emulsions of high silver content

Manufacturer	Film type	R 1 m. sensitivity
Agfa Gevaert	Structurix D 4	5
Agfa Gevaert	Mamoray 2 (= Structurix D 7)	100
Kodak	Crystallex	10
Kodak	Industrex	325
Kodak	Kodorex	650

100 to 170 only an insignificant increase in quantum mottle appeared. The interesting observation was that quality rapidly deteriorated along with the increase in visibility of the quantum mottle. The sensitivity region between 100 and 170 examined without magnification appeared to combine the highest possible information with the lowest roentgen dose. Less sensitive films seemed to require magnification to be differentiated from optimal films. More sensitive films generally contained less information.

One situation arose in which a sensitivity higher than 170 proved to be justified. When the phantom thickness increased from 5 cm to 7 cm, image quality suffered a remarkable decrease. It appeared that sensitivity 325 differed a little from lower sensitivities that it may well be recommended for the examination of thick breasts. Even in this situation, however, the highest sensitivity of 650 appeared to impair the image quality to such a degree as to preclude its use altogether.

Discussion

The present investigation of non-screen film in radiography of the female breast has disclosed certain important facts that have not been universally recognized before. The first of these was that a film with a high silver content is always to be preferred to one of equal sensitivity but with a lower silver content. The direct comparison between two emulsions with different silver contents made it clear that the difference lies in the higher quantum mottle of the emulsion with a lower content. The comparison between emulsions having high silver contents but differing in sensitivity likewise proved the quantum mottle to be of great significance for image quality. Certain films should thus not be recommended for this examination technique owing to their low silver content, namely the 90 second film intended for mammary radiography, the medical non-

screen film for roll machine processing and the Medichrome film meant for use with screens although applied to mammary roentgenography without screens. These films can be replaced by industrial film of the same sensitivity and high silver content having the capacity to absorb more photons and thus produce more information. BARTH *et coll.* (1972) were unable to detect any differences between a 90 second film and an industrial film of high silver content. However the two films were not placed in the same envelope but were corrected for comparison by varying the exposure. quantum mottle was ignored. Another interesting result was the discovery that the sensitivity of a non screen film of high silver content lies within narrow limits for the achievement of the best quality without unduly high roentgen doses. The sensitivity should not be set below 100 in the terms of this investigation (Table 2) unless secondary magnification be contemplated only seldom where the breast is thick, is it advantageous to raise the sensitivity up to 325. The optimum seems to be at 100 to 170. It deserves mentioning that the Kodak films Crystalex and Industrex may both be processed with the new chemicals for 6 minutes. As regards the Industrex film with its high sensitivity of 325 the utmost care should be taken to keep the rolls of the processing machine clean and even to avoid wet pressure marks.

A good example of how films of different sensitivity should not be compared as to recording capacity was presented by PRICE & BUTLER (1970). They put two industrial films of different sensitivity into the same envelope exposing them simultaneously. They appeared surprised to find that the film with the higher sensitivity gave a recording that was as good as that of the other film. They recommended the use of high sensitivity films. The authors did not realize that the two films gave recordings with the same quantum mottle since they were exposed to about the same dose and had the same absorptive capacity. The signal/noise ratio was thus the same in both recordings, in spite of the difference in film sensitivity. What they did prove however was the fact that this ratio is of the utmost importance while the other characteristics of non screen film of high silver content are of limited significance.

Radiography of the breast with a molybdenum target and filter and films considered optimal in quality unfortunately leads to high roentgen doses to the patient. It would appear that if the breast has an absorption factor of 5 cm of water the dose will be between 10 and 20 rad per exposure. This price can be paid only in situations where disease is probable it cannot be accepted for health controls other than possibly of the aged. This hazard has been ignored to a surprising degree by earlier authors. Much ingenuity has been applied to the question whether the molybdenum anode really possesses an advantage over its tungsten counterpart (MIKA & REISS 1968, JAEGER 1969, HACH 1972, KYZER 1972). The rendering of optimal contrast of the image regardless of roentgen

dose appears however always to have constituted the primary aim. The data available from the investigations mentioned indicate that the molybdenum target will give a higher contrast than the tungsten anode provided that the absorption of the breast does not amount to more than 4 to 5 cm of water. The present authors have been able to confirm this by means of phantom examinations of their own. However the total dose and consequently the quantum mottle have not been incorporated into the calculations so it is not known which technique gives the better information for the lowest roentgen dose to the patient. If this problem is to be analysed the minimum number of photons necessary to produce a noise free recording should first be recognised. An attempt should then be made to establish a technique including target material and filtering that can make this number accessible to the film so as to supply the best contrast in the representation and the least unnecessary absorption within the patient. The present investigation indicates the optimal non screen film sensitivity that can be obtained. If the number of photons required to produce the image with such a film were known access would be gained to important basic information of a kind that would open new ways in the search for a good low dose technique for mammary radiography.

One major reason underlying the generation of the high radiation doses in radiography of the breast lies in the low efficiency of the film regardless of whether it has a high silver content or not. A striking example of how much further information may be extracted from a given roentgen dose if the efficiency of the film be increased appears in Fig. 2 c. Here two films have been placed one on top of the other producing extreme density, a copy of this double roentgenogram exhibited a high degree of contrast. If there were films of such efficiency although perhaps still not giving the high density of the two combined films the extremely soft roentgen rays of the molybdenum target might be superfluous. It must be emphasized that too little interest has been given to the film problem in the examination procedure under discussion. Today only films and screens developed for radiography at higher tube potentials are used. Special films appear to be as important as special roentgen tubes for this type of roentgen examination. At present however the industrial roentgen films seem to give the best recording.

One important practical question in the use of industrial films concerns the usefulness of the new chemicals for the processing of other types of roentgen film. A roll machine cannot be left working all the time at 6 minute processing unless mammary radiographies are constantly being performed. It should be possible to employ the machine at a shorter processing time when necessary. Since these reversions must be rapid it should be a matter of the speed of the driver only and not of the temperature. It has been found possible to use the Pakorol alternatively

for 2.5 and 6 minute processing times with the developer temperature at 30-35 °C. The shorter processing is reserved for the usual screen films (Agfa Gevaert Curix RP 1) and medical non screen film (Agfa Gevaert Osray M). With the temperature raised to 35 °C, 90 second processing may be carried out for screen films. If the Mammary film is then developed at 6 minute processing time slight basal fog appears but is not disturbing. At this latter temperature a gain in sensitivity occurs so that the roentgen dose may be reduced to 60 to 70 per cent.

SUMMARY

A comparison has been made between a series of two roentgenograms of the female breast: one intended for 90 second processing the other containing more silver for 6 minute processing in a roll machine. The latter produced considerably better detail. The method as to how industrial film with a high silver content may be incorporated into the processing routine of the average clinic is discussed.

ZUSAMMENFASSUNG

Es wurde ein Vergleich zwischen Serien von zwei Röntgenbildern der weiblichen Brust vorgenommen: das eine abgepaßt für eine 90 Sekunden Entwicklung, das andere das mehr Silber enthält für eine 6-Minuten Entwicklung in einer Drehmaschine. Letzteres gab wesentlich bessere Einzelheiten. Weiterhin diskutieren die Verfasser die Methode wie industrielle Filme mit einem hohen Silbergehalt in die Entwicklungsroutine einer gewöhnlichen Klinik aufgenommen werden können.

RÉSUMÉ

Les auteurs ont comparé une série de couples de radiographies de seins de femme: une de ces radiographies était faite pour un développement en 90 secondes et l'autre sur un film contenant davantage d'argent était faite pour un développement en 6 minutes dans une machine à rouleaux. Ces dernières radiographies ont fourni des détails bien meilleurs. Les auteurs examinent comment on pourrait introduire dans l' développement de routine en radiologie courante des films industriels qui contiennent davantage d'argent.

REFERENCES

- BACKSTROM H. och LUNDH A. Det röntgenografiska materialet och dess behandling (In Swedish) In: Fotografisk handbok. Edited by H. Backstrom. Natur och Kultur, Stockholm 1959.
- BARTH V., DEURINGER K. und von BABO H. Erst Erfahrungen mit einem neuen Mammo grafiefilm für 90 Sekunden Maschinenerarbeitung. Röntgen M. 28 (1972) 150.
- COAN R. L. Mammography. Charles C. Thomas, Springfield, Ill. 1964.

- and FINE J O. Phantoms for evaluating mammography techniques and roentgenographic detail. *Amer J Roentgenol* 102 (1968) 936
- FOUZZOLA F. Mammography—practical hints and critical considerations. *X ray Bulletin* (Published by Agfa/Gevaert) 18 (1971) 30
- GERMOND CORRE J, BERGER E M and DELPINO L. Mammography. Some remarks on techniques. *Radiol Clin N Amer* 3 (1965) 389
- HERVEL M B and BRUYER J W. Advances in mammographic technique. *Amer J Roentgenol* 108 (1970) 44
- HAGU G. Betrachtungen zur optimalen Mammographische Technik. *Fortschr Röntgenstr* 117 (1972) 298
- JAEGER H. Physikalisch-technische Grundlagen zur roentgenphotografischen Abbildung von Weichteilen. *Röntgen Bl* 22 (1969) 323
- KYMA K. Röntgenspektrometrie und roentgenosmetrische Untersuchungen der Strahlenqualitäten für Weichstrahlungsaufnahmen. *Fortschr Röntgenstr* 116 (1972) 818
- LUNDS A. Personal communication (1972)
- MIKA N und REISS K. H. Optimierung der Röntgenbelichtungstechnik mit Hilfe der Halbleiterspektrometrie. *Röntgenpraxis* 21 (1968) 164
- MIRVAGI H, TEASKE J O and YOUNGER J E. Conting and breast compression. An aid in mammographic diagnosis. *Radiology* 91 (1968) 579
- PAX J L and BUTLER P D. Mammography symposium—2. Toward a technique. *X ray Focus* (Published by Ilford) (1969) 12
- — The reduction of radiation and exposure time in mammography. *Brit J Radiol* 43 (1970) 251
- RECHENOW G M. Mammography symposium—4. *X ray Focus* (Published by Ilford) (1969) 10
- STRAX PH and OPPENHEIM A. New apparatus for mass screening in mammography. *Amer J Roentgenol* 102 (1968) 941
- YOUNG G H. Mammography symposium—3. *X ray Focus* (Published by Ilford) (1969)

HIGH DOSE UROGRAPHY IN ADVANCED RENAL FAILURE

II Influence on renal and hepatic function

N MILMAN and P STAGE

A prerequisite for routine employment of high dose urography in renal failure is reasonable atoxicity of the contrast medium, especially as regards the organs of excretion i.e. the kidneys and liver.

Reports dealing with the nephro- and hepatotoxicity of urographic contrast media in advanced renal failure and end stage renal disease are not extensive. The present work was consequently aimed at renal and hepatic function in the periods before and following high dose urography in this type of patient.

Material and Methods Renal and hepatic parameters were recorded in connection with the high dose urographies described in the previous paper, the material being divided into four groups according to the duration of renal disease (STAGE *et coll.* 1973). From this material three patients had to be excluded: two because of a pre urographic creatinine clearance of 0.0 ml/min and one by reason of insufficient recording of renal function. The material thus comprised 47 patients all in advanced renal failure with pre urographic 24 hours endogenous creatinine clearance (\approx creatinine clearance) below 12.0 ml/min, made up of 24 males and 23 females, mean age 49 years (range 19 to 79 years). None of the patients suffered from multiple myeloma, diabetes mellitus, hepatic insufficiency or urolithiasis.

Submitted for publication 20 February 1973

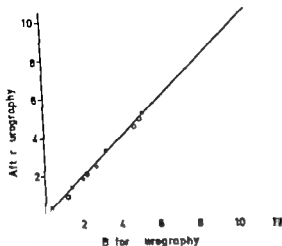


Fig 1 Creatinine clearance before and after one (●) or two (○) urographs in 14 patients on chronic dialysis (group 1)

The technique of urography has been described in the previous paper Part I (STAGE *et coll* 1973). A dose of 150 ml Urografin 76 % (sodium and methylglucamine diatrizoate) equivalent to 1.5 to 3.7 ml/kg (mean 2.5 ml/kg) was administered without preliminary fluid restriction or laxatives.

Serum creatinine and creatinine clearance in each patient were recorded as the averages of 2 to 7 measurements within 8 days before urography. Following urography these two data were recorded daily during the first 7 and 4 days respectively. Impaired renal function indicated further control until the renal function had stabilized. The total post urographic observation period ranged from 7 to 47 days. — Serum glutamic pyruvic transaminase was recorded in 36 of the 47 patients as an average of 2 to 3 measurements performed within 6 days before urography and daily the first 4 days following urography.

Results

Fig 1 gives the clearance before and after urography in 14 patients on chronic dialysis (group 1). No significant change was evident (Wilcoxon's test $p > 0.20$).

Fig 2 referring to 25 patients in steady state uremia (group 2) presents post urographic mean changes as percentages of pre urographic values of creatinine clearance and serum creatinine. The levels of significance for these changes as judged by Wilcoxon's test are indicated in Tables 1 and 2. A significant decrease in creatinine clearance greatest on the second day followed

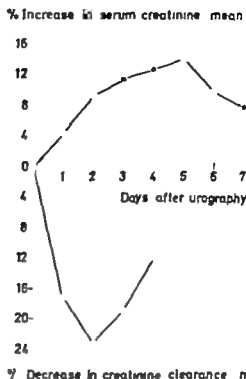


Fig. 3. Changes in serum creatinine and creatinine clearance following urography in 25 patients in steady state remission (group 2).

% Decrease in creatinine clearance mean

by a significant rise was evident. The changes in creatinine clearance were accompanied by inverse but delayed significant changes in serum creatinine. Neither the creatinine clearance nor serum creatinine returned to pre urographic levels within the first week of observation.

The maximum and subsequent minimum decrease in creatinine clearance following urography in all 25 patients is demonstrated in Fig. 3, while Fig. 4 gives the concomitant changes in serum creatinine in the same group of patients. Fourteen of the 25 patients presented both an initial decrease in creatinine clearance exceeding 10 ml/min, and an initial increase in serum creatinine exceeding 0.06 mmol/l. Figs 5 and 6 indicate that the maximum changes in the renal parameters occurred in these patients within 20 days after urography and pre urographic levels were reached within 45 days following urography in all but 2 patients (Cases 13 and 36).

The initial decrease in renal function appeared to be independent of the underlying disease.

Table 1

Significance of change in creatinine clearance following urography in 25 patients with steady state uraemia (group 2)

	Days		
	0-2	2-4	0-4
Creatinine clearance	decrease	increase	decrease
$p < 0.01$			
$0.05 < p < 0.1$			
	(= 20)	(= 20)	(= 21)

Day 0 = before urography

Fluid was restricted accidentally before urography in 5 patients. These presented a tendency although not statistically significant towards a more marked initial increase in serum creatinine.

Positive correlation between contrast dose and initial increase in serum creatinine (Spearman's test $p < 0.05$) could be demonstrated although correlation between the pre urographic renal function or the degree of proteinuria and post urographic decrease in renal function was not observed.

In groups 3 and 4 (8 patients with acute exacerbation in chronic and acute renal failure) a permanent decrease in renal function caused by urography never occurred. However in one patient suffering from acute tubulo-interstitial nephropathy slowly resolving urography was followed by a distinct temporary delay in rate of improvement.

Table 2

Significance of change in serum creatinine following urography in 25 patients with steady state uraemia (group 2)

	Days				
	0-1	1-2	1-4	4-7	0-7
Serum creatinine	increase	increase	increase	decrease	increase
$p < 0.01$					
	(= 2)	(= 2)	(= 2)	(= 22)	(= 23)

Day 0 = before urography

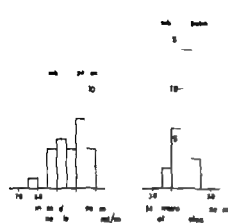


Fig 3

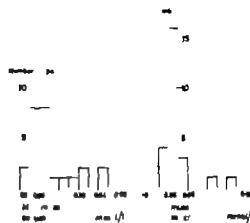


Fig 4

Fig 3 Patients distributed according to maximum and subsequent minimum decrease in creatinine clearance in the total post urographic observation period (group 2)

Fig 4 Patients distributed according to maximum and subsequent minimum increase in serum creatinine in the total post urographic observation period (group 2)

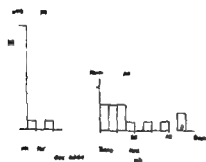


Fig 5

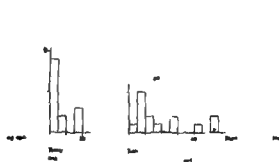


Fig 6

Fig 5 The 14 patients presenting post urographic decrease in creatinine clearance exceeding 1.0 ml/min and an increase in serum creatinine exceeding 0.06 mmol/l distributed according to time for maximum decrease in creatinine clearance and time for reaching pre urographic level (group 2)

Fig 6 The 14 patients presented Fig 5 distributed according to time for maximum increase in serum creatinine and time for reaching pre urographic level (group 2)

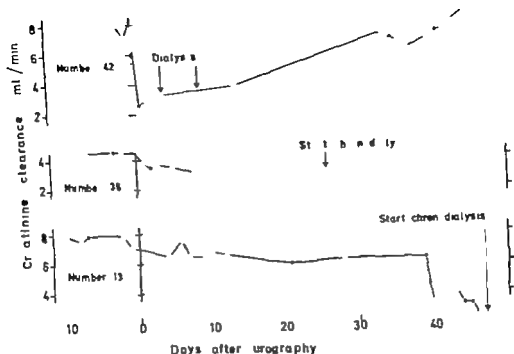


Fig 7 Case reports Changes in creatinine clearance in relation to urography in 3 patients

Case reports

In the total series 3 patients in group 2 presented atypical changes. Two had permanent slight impairment of renal function and one had a severe and prolonged but reversible renal impairment following urography.

Case 13 Woman aged 49 years (Fig 7) suffering from chronic primary pyelonephritis and in whom during the last 15 years the renal function had been gradually decreasing. Urography (contrast dose 2.4 ml/kg) was preceded by fluid restriction. Following the examination the creatinine clearance dropped from an average of 7.6 to 6.3 ml/min and the serum creatinine rose from 0.71 to 0.98 mmol/l and later stabilised at 0.91 mmol/l. The diuresis was unchanged. The most likely explanation for the decrease in renal function seemed to be spontaneous progression of the disease. Although the administration of contrast medium possibly in connection with dehydration may also have been of some significance.

Case 36 Woman aged 52 (Fig 7) suffering from chronic primary pyelonephritis in whom during the previous 15 years the renal function had been gradually decreasing. Urography (contrast dose 3.7 ml/kg) was followed by a permanent drop in creatinine clearance from 4.5 to 3.0 ml/min and an increase in serum creatinine from 0.52 to 0.62 mmol/l. The patient received the highest dose of contrast medium administered; the most likely explanation for the renal impairment.

Case 42 Man aged 35 years suffering from chronic glomerulonephritis (Fig. 7). Following urography (contrast dose 2 ml/kg) the creatinine clearance fell from 7.8 to 2.7 ml/min and the serum creatinine rose from 0.99 to 1.58 mmol/l; the patient became oliguric and in need of dialysis. Renal function gradually improved but the pre urographic level was not reached until 45 days after the urography. The causal relation between the examination and the renal impairment seems obvious.

No alteration in hepatic function as judged from serum glutamic pyruvic transaminase was observed following urography in 36 patients; even 4 patients with elevated pre urographic values presented no change.

Discussion

The administration of high doses of diatrizoates, even in patients with moderate renal failure, is generally considered a safe procedure and unaccompanied by further deterioration in renal function. This assumption is confirmed by experimental investigations in animals (LINDQREN 1961; STOKES & BERNARD 1961). These authors observed no functional or histologic changes in the kidneys following injection of large doses of diatrizoates directly into the renal artery, while the administration of acetrizoates caused severe renal damage. BENOTSSOV *et coll.* (1968) observed no significant change in the clearances of inulin and para-aminohippurate after high dose urography with metrizoate in patients with moderately decreased renal function.

BARTLEY *et coll.* (1969) estimated renal function in moderate renal failure by single measurements of serum creatinine and renal concentrating capacity before and after the injection of diatrizoate without observing any consistent alterations. DAVIDSON *et coll.* (1970) in patients with various degrees of renal failure were unable to demonstrate any significant change in renal function as judged by serum creatinine and the half time of serum iodine during the first 3 days following urography with about 2 ml diatrizoate 60% or iothalamate per kg body weight. SCHWARTZ *et coll.* (1963) however reported a transient rise in serum creatinine after urography with small doses of diatrizoate in 4 out of 131 patients with various degrees of renal failure.

STAGE *et coll.* (1971) performed urography after previous fluid restriction and purging with 80 to 150 ml diatrizoate 76% in patients with various degrees of impaired renal function; they noted a significant transient increase in serum creatinine but no permanent reduction in renal function. The higher the pre urographic serum creatinine level the greater the frequency and magnitude of the post urographic rise appeared to be. As clearance examinations were not performed it was impossible to exclude the transient rise in serum creatinine being caused by dehydration, either before the examination or as a sequence of osmotic diuresis following the contrast medium.

The present results are in accordance with those of SCHWARTZ et coll. The transient decrease in renal function (Fig. 2) seems to be due to a nephrotoxic effect of the contrast medium. Dehydration as an alternative explanation is unlikely as unrestricted fluid intake was allowed both before and after the examination and neither of the patients had any signs of dehydration judged by the clinical condition and weight curve.

The transient decrease in renal function may be so marked that dialysis has to be performed (Fig. 7 Case 42) but a permanent although moderate decrease caused by the examination was also observed (Fig. 7 Case 36).

The risk of further renal injury increases with the amount of contrast medium administered as indicated by the correlation between the dose and the post urographic increase in the serum creatinine recorded. It would appear that the dose administered should not exceed 2 to 3 ml diatrizoate 76% per kg body weight.

There appeared to be no definite difference in the impairment of renal function between patients who were fluid restricted and those not so controlled. However dehydration per se is a hazard to many uremic patients and should therefore be avoided even in preparation for urography. Urography in multiple myeloma and diabetes in connection with dehydration seems to imply a special risk of renal injury (Mizers & WITTON 1971; PILLAY et coll. 1970). The present material without these conditions suggested that the transient decrease in renal function was independent of the nature of the renal disease.

That the liver is the main alternative excretory pathway for contrast media has led to hepatic function examinations following urography (SHERWOOD et coll. 1968; DAVIDSON et coll. 1970). The present results confirm their findings of no changes.

In conclusion the administration of large doses of contrast medium in advanced renal insufficiency even without previous dehydration implies a risk of further renal impairment generally slight and transient although sometimes marked and permanent. However compared with the diagnostic value the risk of further renal impairment hardly constitutes a contraindication to high dose urography even in end stage renal disease.

SUMMARY

Renal and hepatic function was evaluated in the periods before and after high-dose urography with an average of 2.5 ml/kg Urografin 76% in 47 patients in end stage uremia by frequent recording of serum creatinine, endogenous creatinine clearance and serum glutamic pyruvic transaminase. A significant transient decrease in renal function in one patient indicating temporary dialysis was noted. No change in hepatic function was observed.

ZUSAMMENFASSUNG

Die Nieren- und Leberfunktionen wurden während der Zeitraum vor und nach hoch dosierter Urographie mit einer mittleren Dosis von 25 ml/kg 76 % igem Urographin bei 47 Patienten mit einer terminalen Urämie durch häufige Bestimmung des Serumkreatinin, des endogenen Kreatininclearance und der Serumglutaminsäure-Pyruvat-Transaminase festgestellt. Es wurde ein signifikantes, vorübergehendes Absinken der Nierenfunktion bei einem Patienten eine vorübergehende Dialyse notwendig machte festgestellt. Es waren keine Veränderungen der Leberfunktion zu beobachten.

RÉSUMÉ

Chez 47 malades en urémie à stad terminal les auteurs ont déterminé les fonctions rénales et hépatiques par des mesures fréquentes de la créatinine sérique, de la clearance de la créatinine endogène et de la transaminase pyruvique glutamique sérique avant et après une urographie faite avec une forte dose d'en moyenne 25 ml/kg d'urografin 76 %. Ils ont constaté une diminution transitoire importante de la fonction rénale chez un malade faisant porter l'indication d'une dialyse temporaire. Ils ont pas constaté de modifications de la fonction hépatique.

REFERENCES

- BARTLEY O, BENGTSSON U and CEDERBOM G: Renal function before and after urography and angiography with large doses of contrast media. *Acta radiol. Diagn.* 8 (1969) 9.
- BENGTSSON U, CEDERBOM G, FALSKEDEN T and JAGENBURG R: Clearances of uretin and para-minohippurate before and after urography using high dosage of contrast medium in patients with renal insufficiency. *Scand. J. Urol. Nephrol.* 2 (1968) 173.
- DIMON A, J. BECKER, J. ROTHEFIELD N et coll.: An evaluation of the effect of high dose urography on previously impaired renal and hepatic function in man. *Radiology* 97 (1970) 249.
- LEDOUX P: Renal circulatory insufficiency after renal angiography. *Acta radiol.* 56 (1961) 423.
- MILMAN G H and WITTON D M: Acute renal failure after excretory urography in multiple myeloma. *Amer. J. Roentgenol.* 113 (1971) 583.
- PILLAY V, ROBERTS P C, SCHWARTZ F D and KARK R M: Acute renal failure following intravenous urography in patients with long standing diabetes mellitus and arteriosclerosis. *Radiology* 95 (1970) 633.
- SCHWARTZ W B, HURVIT A and EITZWIKER A: Intravenous urography in the patient with renal insufficiency. *New Engl. J. Med.* 269 (1963) 277.
- SHERWOOD T, BRACKENRIDGE A, DOLLERY C T et coll.: Intravenous urography and renal function. *Clin. Radiol.* 19 (1968) 296.
- STAGE P, BERG E, FOLKE K and KARK R: Urography in renal failure. *Acta radiol. Diagn.* 11 (1971) 337.
- , MILMAN N and BERG E: High-dose urography in advanced renal failure. I. Evaluation of diagnostic value. *Acta radiol. Diagn.* 14 (1973).
- STONES M J and BICKFORD H R: Nephrotoxicity of iodinated contrast media. Quantitative effects of high concentration upon glomerular and tubular functions. *Ann. Surg.* 153 (1961) 299.

BRAIN VOLUME IN ACROMEGALY

An encephalographic investigation

CLAES RADBERG

Endocrine disturbances are not only associated with changes in the actual hormone producing organ but also, as a rule with functional and morphologic abnormalities elsewhere in the body. Judging from the literature possible cerebral changes in various endocrine disorders has received but little attention. Movsas et coll (1971) demonstrated encephalographically that cortical atrophy of the cerebrum and cerebellum was common among 31 patients with Cushing's disease. To elucidate the atrophy more closely they also compared encephalograms of 64 patients with acromegaly and with those of 36 with chromophobe adenoma. They found cortical atrophy to be more common in chromophobe adenoma than in acromegaly but by no means so common as in Cushing's disease.

No comparison was made with a series of so-called normal encephalograms. Neither did they describe the appearance of the ventricular system in patients with acromegaly or chromophobe adenoma only in patients with Cushing's disease. They found no correlation between the severity of cortical and central atrophy. Hatan & Gertz (1972) found ectasia of the larger cerebral arteries in 13 patients with acromegaly and suggested that the ectasia belonged to the picture of acromegalic splanchnomegaly.

From the Departments of Diagnostic Radiology, Region sjukhuset University of Linköping 581 85 Linköping, Sweden. Submitted for publication 28 February 1973.

It would appear that no other investigations, at least not radiologic, have been published on the relation between cerebral changes and endocrine disorders.

The present investigation of the ventricular system and the size of the grooves as demonstrated in encephalograms of patients with acromegaly was initiated by the observation of unusually small ventricular systems in patients with this disease. The findings were compared with those in patients with chromophobe adenoma and in a control material, i.e. encephalograms of patients without demonstrated intracranial lesion. A preliminary report was presented by the author in 1972.

Material and methods

Excluded from the material were all cases with a large extrasellar part of the adenoma that unequivocally compressed or displaced the lateral ventricles or that was thought to obstruct the flow of the CSF and cases with hydrocephalus of other origin or where intracranial operations had been performed before the encephalographic examination. Three groups of encephalographies were chosen.

Group with acromegaly (A) This group consisted of all patients with clinically verified acromegaly and examined encephalographically at Sahlgrenska Sjukhuset, Gothenburg, in 1957—1972 (all together 19 patients) and 11 patients examined at Regionsjukhuset Linköping, in 1966—1972. The group consisted of 30 patients aged 26—70 years, 16 men (mean age 43.1) and 14 women (mean age 51.0). In 12 patients the adenoma had a suprasellar part that reached 5 to 30 mm above the entrance of the sella turcica.

Group with chromophobe adenoma (C) This group comprised encephalograms of 12 randomly selected patients examined at Sahlgrenska Sjukhuset in 1954—1966 and 22 examined in 1964—1972 at Regionsjukhuset. The group was made up of 34 patients aged 21—70 years, 19 men (mean age 48.4) and 15 women (mean age 42.9). In 30 cases a suprasellar part of the adenoma extended 2—28 mm above the entrance of the sella.

Control group (N) This material was selected consecutively from the archives of the department of diagnostic radiology Regionsjukhuset obtained during the period 1960—1968. Only encephalograms of not demented patients (BURKHORST & DAVIES 1963) in whom neurologic examination had revealed nothing abnormal and in whom the indication for the examination had been headache, dizziness or epilepsy were accepted. Encephalograms with any notable asymmetry or cases with subdural gas or where the width of the anterior horn exceeded one

NUMBER

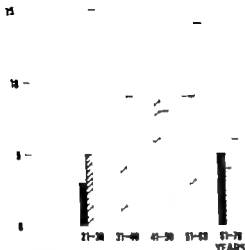


Fig. 1 Age distribution and number of patients in the group with acromegaly (▨ 30 patients), the group with chromophobe adenomas (□ 34 patients) and the control group (■ 52 patients).

third of the greatest width of the skull on that side, as measured to the tabula interna, i.e. Lundgren's ratio (LUNDGREN 1951) were not included.

There were 52 patients, aged 22—66 years, 34 men (mean age 44.9) and 18 women (mean age 40.9). The cases were intentionally chosen from patients who had been examined a long time previously in order to allow for a follow up of possible cerebral disease at the time of the examination.

The age distribution of the patients in the various groups is given in the histogram (Fig. 1).

Encephalographic technique. All encephalographies had been performed with the fractionated technique described by LUNDGREN (1949) and with oxygen as contrast medium. The amount of gas in the lateral ventricles was roughly equal and when the patient was supine extended about 1 cm dorsally to the inter-ventricular foramina (LARSSBY & LUNDGREN 1940). Special attention had been given to the filling of the suprasellar cisterns and the subarachnoid space of the convexity. If an expanding suprasellar process had been suggested the investigation, as a rule, included tomography.

Twenty-seven of the examinations (A1-C7-N19) had been performed with Lysolm's skull table with a focus-film distance of 70 cm. 49 (A15-C17-N17) with Mimer I (FREDZELL & LUNDGREN 1959) with a distance of 80 cm between the focus and the object plate which means a focus-film distance of barely 84 cm and the remaining 40 (A14-C10-N16) with Mimer III (FREDZELL et coll.

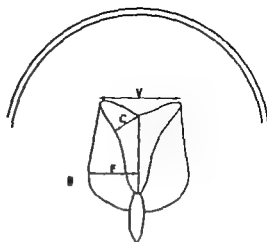


Fig. Sketch of encephalogram with patient supine. V=maximum width of both ventricular bodies (body span). C=septum caudate distance. F=maximum width of anterior horn. B=half maximum internal skull width.

1968) with a focus object distance of 80 cm to a plane through the auditory canal. In a p projection with the patient supine this means a focus film distance of about 94 cm.

Measuring technique. To appraise the size of the ventricular system and of the grooves various distances were measured (KNUDSEN 1958) with a rule graduated in millimetres. The dimensions measured were used uncorrected for roentgenographic enlargement. A ratio was most often used instead of absolute values in the evaluation of the dimensions in order to minimize or eliminate differences in roentgenographic enlargement due to variations of focus object film distances, length of the patient's skull and thickness of the head rest etc. Distances in the frontal plane were thus divided by the value found for the width of the skull, measured to tabula interna. In this way it was also possible to take into account the correlation between the size and shape of the ventricular system and of the skull. Numerical estimation of this correlation is necessary in comparing volumes of the ventricular system (EVANS 1942, LINDQVIST 1951, SCHIERSMANN 1952, LAUBER 1965, BERG & LÖNNER 1966, LÖNNER 1968). In the supine a p view with the lower part of the orbit projected at the level of the upper border of the pyramid the following measurements were obtained (Fig. 2): (1) the greatest width of anterior horn (F) (2) the septum caudate distance (C) (TROLAND et coll. 1946, ENGBERG & SALLAAS 1964, LAUBER 1965) (3) the greatest width of the cella media or ventricular body span (V) (BAIJN 1959, BORHENTZ & DAVIES 1963) and (4) the half greatest width of the skull, as measured to tabula interna (B).

Table 1

Result of the factor analysis of the different measurements in the three groups A, N and C

Ratio and dimensions with demonstrable differences	Level of statistical significance (A = acromegaly, C = chromophobe, N = normal, Y < 40 yrs, O > 41 yrs)	
L. ant. horn: absolute values (F)	A < N < C	(p < 0.05)
	N < O	(p < 0.05)
Ratio L. ant. horn (F/B)	A < N < C	(p < 0.05)
	N < O	(p < 0.05)
	O > Y	(p < 0.05)
Ratio smaller ant. horn (F min/B)	A < N	(p < 0.05) N < C (p < 0.05)
Ventricular body span (V)	A < N	(p < 0.05) N < C (p < 0.05)
	N < O	(p < 0.05)
Ratio ventricular body span (V/B)	A < N	(p < 0.05) A < C (p < 0.05)
	N < O	(p < 0.05)
Height smaller ant. horn	A < N < C	(p < 0.05)
Smaller septum caudate distance (C min)	A < N	(p < 0.05) A < C (p < 0.05)
	N < O	(p < 0.05)
Width of third ventricle	A < N	(p < 0.05) N < C (p < 0.05)
	N < O	(p < 0.05)
Width of the grooves in the cerebrum	A < N < C	(p < 0.01)
Thickness of epipharynx	A > N	(p < 0.01)
	A > C	(p < 0.01)
Ratio between L. and R. ant. horn	Left > Right	(p < 0.01)

In a lateral projection with the patient supine and the central ray at the level of the anterior part of the anterior horn measurements were obtained of the height of the smallest lateral ventricle about 1 cm anterior of the interventricular foramen where there is normally a small inward bulge in the floor of the anterior horn caused by the most anterior and lower part of the caudate nucleus. The height was measured perpendicular to the roof of the anterior horn (Fig. 7).

The height of the suprasellar part if any of the adenoma was measured from the entrance of the sella to the upper pole of the process.

The width of the grooves in the cerebrum was measured not only on films exposed in supine position but also on other films where they were gas filled. Two values were noted viz. the width of the majority of the wide and the narrow grooves. Two values were noted also when all the grooves were of uniform width. The grooves in the cerebellum were not measured because no special technique had been used to fill them with gas in the present material (TIEBAUT *et coll.* 1963).

The temporal horns and the height of the fourth ventricle were measured on suitable views and tomograms.

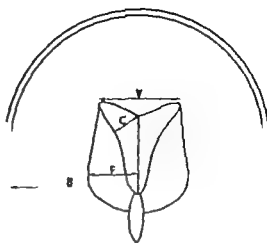


Fig 2 Sketch of encephalogram with patient supine V=maximum width of both ventricular bodies (body span) C=septum caudate distance F=maximum width of anterior horn B=half maximum internal skull width

1968) with a focus object distance of 80 cm to a plane through the auditory canal. In a p projection with the patient supine this means a focus film distance of about 94 cm.

Measuring technique To appraise the size of the ventricular system and of the grooves various distances were measured (KNUDSEN 1958) with a rule graduated in millimetres. The dimensions measured were used uncorrected for roentgenographic enlargement. A ratio was most often used instead of absolute values in the evaluation of the dimensions in order to minimise or eliminate differences in roentgenographic enlargement due to variations of focus object film distances, length of the patient's skull, and thickness of the head rest, etc. Distances in the frontal plane were thus divided by the value found for the width of the skull, measured to tabula interna. In this way it was also possible to take into account the correlation between the size and shape of the ventricular system and of the skull. Numerical estimation of this correlation is necessary in comparing volumes of the ventricular system (EVANS 1942, LINDGREN 1951, SCHIERSMANN 1952, LAUBER 1965, BERG & LONNUM 1966, LODIN 1968). In the supine a p view with the lower part of the orbit projected at the level of the upper border of the pyramid the following measurements were obtained (Fig 2): (1) the greatest width of anterior horn (F) (2) the septum caudate distance (C) (TROLAND et coll 1946, ENGBET & SKRAASTAD 1964, LAUBER 1965) (3) the greatest width of the cella media or ventricular body span (V) (BAUJN 1959, BURJEN & DAVIES 1963) and (4) the half greatest width of the skull as measured to tabula interna (B).

The ratio for the smallest septum-caudate distance (G_{\min}) was not examined with factor analysis but with an earlier performed t test and the following differences were found

$$A < N (p < 0.05)$$

$$A < G (p < 0.05)$$

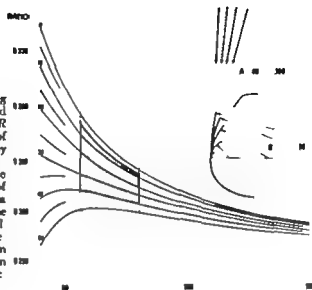
No other significant differences were found. Evaluation of the results of the investigation requires knowledge of the parameters influencing the ratios and measurements of the CSF spaces and the extent of such influence.

Parameters causing variation of ratios in the anterior part of the lateral ventricle. In the present investigation these ratios were defined as quotients between distances measured in the ventricle and the greatest half width of the skull. The ratios were used for estimating the relation between the size of the ventricular system and that of the skull. In order to assess to what extent roentgengeometric and anatomic factors influence ratios, an imaginary model of a skull with a ventricular system in the $a-p$ projection (Fig. 3) was used.

The tangential point that defines the projected width of the skull varies with the value of A which results in a proportionally different enlargement of F and the tangential width of the skull, which in turn naturally causes a change in the ratio. The ratio will also vary with the value of R . A larger R will result in a smaller ratio as if the volume of the skull had increased. It is of course true that with a given value for the greatest width of the skull, a larger radius will embrace a larger volume of the skull, and the ratio is constructed to reflect such a change.

It may be questioned whether it is justified to correlate the width of the ventricular system with the greatest outer width of the skull (Berg & Lofgren 1966) because it is the volume of the ventricular system and the interior volume of the skull that are correlated and this volume should reasonably be more closely correlated with the distance to the tabula interna than with the true outer width. Furthermore there might be a still closer correlation if width measurements in the ventricular system are compared to skull measurements to the tabula interna in the same frontal plane than if these measurements were done more dorsally. To measure the greatest width of the skull at the level of the anterior horns is technically difficult. The roentgenographically measured inner width of the skull (projected width) lies closer to the level of the anterior horns than the greatest outer width at least with the focus-object distances conventionally used. The radius R was selected to analyse the effect of variation in the shape of the skull on the ratio since different shapes of skulls of one and the same greatest width and volume might perhaps give different values for the ratios (Fig. 4). Further the ratio may be affected by the variation in the distance H between the measurement in the ventricle and the greatest width of the skull.

Fig 4 Upper right A varying distances between the focus and the greatest width of the skull R varying radius of the curvature of the skull in the plane defined by the tangential ray. Bold arrow the varying divergence of the beam. Diagram The variation of a ratio with A and R . Dotted area denotes the variations of these factors found in the test material. Area limited by broken lines denotes the total possible variation that results when the variation (1 SD) of H is taken into account.



In the diagram (Fig 4) the following fixed values were chosen $F = 20$ cm, $B = 70$ cm and $H = 5.8$ cm. The ratio was calculated for the values 40, 41, 42, 150 cm of A and for each of these values the ratio was calculated for the values 0, 5, 10, 50 cm of R . The diagram shows how the ratio varies under these conditions. If a limitation is made because of the focus-object distances used in the present investigation, only values of 56–80 cm will be found for A . This analysis showed that the ratio varies inversely with the film-object distance and naturally also inversely with the width of the skull in the area of the tangent points on the tabula interna, which denote the maximum widths of the skull in the roentgenogram.

With knowledge of the influence of R on the ratio an attempt was made to find out whether any difference existed in the curvature defined by R between the group with acromegaly and the control group.

In a test material of 11 randomly selected patients with acromegaly and 11 of the controls, axial views of the skull were analysed. It was assumed that the outline of the skull in the axial projection coincided approximately with the curvature of the calvaria at the level where the greatest width of the skull was measured in the roentgenogram. The radius of the curvature of the skull was measured in the following way. For each of the three focus-film distances used a beam of diverging lines was traced on a transparent mask. The film was placed on this mask so that the bundle of lines corresponded to the rays in the α p projection of the encephalogram (Fig 4 right). The point where the rays formed a tangent to the

Table 2

Value of radius R (cm) indicating curvature of the skull in test material of 11 acromegalic patients and 11 controls

Normal	Acromegalic
13	17
31	24
10	35
6.5	16
20	10
37	12
37	37
18	12
28	11
9	20
13	12
Mean = 19.4	Mean = 17.4
SD = 10.1	SD = 9.5

skull were marked, as was the greatest width of the skull. From these two points the radius of the curvature could be calculated. Since it was found that the curvature of the tabula interna was less well defined, the radius of the tabula externa was used because it was regarded as fully representative of the curvature. The distribution of the radius is given in Table 2. No significant difference was found between the two materials. If allowance be made for the skull radius measured the variation in the ratio can be limited further to the dotted area in Fig. 4.

To estimate possible systematic difference of the value of H the sagittal distance between the frontal part of the large wings (which corresponds to the anterior part of the ventricular system) and the greatest width of the skull was measured in the same test material also in the axial projection. No statistical difference was found between the two materials in this respect either. The mean value of this distance in the group of acromegalics was 5.7 cm with a standard deviation of 0.8. Corresponding value for the control group was 5.9 cm with a standard deviation of 0.5.

If allowance be made for the variation of H with 1 SD and the effect it might have on the ratio the range of the ratio will be that given by the broken lines beside the dotted area in Fig. 4. It is clear that the variation in the radius (R) has a greater effect than the focus object distance (A).

Summarising, the statistical differences found cannot be explained by differences in R , H and A between the three materials. Also other ratios refer to the anterior part of the ventricular system, for which reason the investigation made, should apply to the same extent for them.

As already mentioned the factor analysis did not reveal any significant difference between the three groups A, C and N regarding the greatest width of the skull measured to the tabula interna.

In the few available publications on the measurement of the size of the skull in patients with acromegaly it is claimed that the volume of the skull does not increase except in those patients in whom the disease has started in puberty (MOORE 1952). The youngest patient with acromegaly in the present material had a somewhat large skull. The patient was 26 years old at the time of encephalography and had had symptoms and signs of acromegaly for 7–8 years. The usually slight increase in the external dimensions of the skull which can be seen in acromegaly in patients in whom the disease appeared after puberty is explained by an increase in the thickness of the vault and of the soft parts. The scalp was fully 1 cm in thickness in one of the cases reported by CUSHING & DAIMOFF (1927).

Variations in measurements of the ventricular system and of the width of the grooves due to technical factors and the encephalographic procedure. With different focus-object distances different parts of the ventricular system will form those contours from which the conventional measurements are made. This variation is different for different measurements, depending on the anatomic appearance of the ventricular system. For instance there is probably no notable variation of the contour forming parts of the surface at the widest width of the anterior horn because these parts are situated on a surface with a very short radius of curvature. On the other hand those contours which denote the end points of the septum-caudate distance and the width of the ventricular body are formed by surfaces having a relatively large radius of curvature. A change in the film-object distance and of angulation may cause a considerable shift in the tangential points. In order to analyse this source of error more closely a p. encephalograms were obtained with the patient supine and with known variation of the focus-object-film distance. The true absolute measurement of the greatest width of the anterior horn, the septum-caudate distance and the width of the body were calculated. No notable variation in size was found in these measurements at examination with focus-object distances between 56 and 80 cm, a range which covers the focus-object distances used in the present investigation. This lack of difference can be explained by the fact that the filling of the ventricular system with gas when the film was exposed, usually extended only down to about 1 cm dorsally to the inter-ventricular foramen and the measurements of the ventricular body (V and G)

were made on or immediately near the contour formed by the interface between gas and fluid at all focus-object distances (TORKILDSEN 1934). That measurements are often made at the gas-fluid level also explains why TROLAND *et coll* (1946) as well as ØRGAARD (1971) found no notable variation in the septum caudate distance on 10° deviation cranially or caudally from the ordinary direction of the beam. Variation in the degree of flexion of the head causes a corresponding shift in the gas-fluid level in relation to the lateral ventricles. Moderate changes in flexion do not cause any notable variation in the measurement because the ventricular system normally is of fairly uniform width in the anterior part of the ventricular body where the gas-fluid level is usually situated. Neither did the factor analysis of the present material show any significant correlation between the method, i.e. varying focus-object distance and any ratio or dimension.

Variation in the measurements of the ventricular system may also be explained partly by the fact that the encephalographic procedure causes a change in the width of the ventricular system. Several authors have observed that the lateral ventricles are wider in films taken 24 hours after the initial examination (EVANS 1942, SCHARTZKE *et coll* 1947, LINDQVIST 1951, LE MAY 1967). JIMOUR (1956) and ØRGAARD (1971) were able to notice a decrease in size of the lateral ventricles about 20 minutes after the gas injection and thought that the gas is irritative and causes cerebral oedema—and that ventricles expand again after about 24 hours by when the oedema has abated. LE MAY (1967) has found that oxygen causes small or no changes in volume of the lateral ventricles. Other investigators claim that the ventricular system is only expanded and then already during the injection of the gas which has been demonstrated in respect of the fourth ventricle by OLSSON *et coll* (1969). More detailed examinations of other parts of the ventricular system have been performed by LAR *et coll* (1972) who showed that gas filling of the ventricular system for air encephalography caused a widening. The relative increase of the ventricular system was most striking when the initial fractions were injected and less when the later injections were given. The authors conclude that the true size of the ventricular system before the first fraction injected is smaller than what is usually recorded at encephalography.

A necessary prerequisite for obtaining a filling of the ventricular system at encephalography is that it is possible to widen the ventricular system (ROBERTSON 1947). This is accompanied by compression of the subarachnoid space and possibly of compressible cisternae. Applied to the present investigation one might speculate that the brain in acromyogaly is of ordinary volume but less yieldable and that the ventricular system accordingly is dilated less than ordinarily during the encephalographic procedure. An observation arguing against this possibility is

however that if the brain were dilated less than normally on injection of gas into the ventricular system, the subarachnoid space and the grooves should be wider and if anything not be smaller than in controls, where one must expect ordinary compression of the grooves during the encephalographic procedure. Conversely that the gas filled ventricular system in patients with chromophobe adenoma is wide cannot be explained by a stronger distension by the gas because if it could, the gas filled grooves would not be wider than ordinarily.

Measurements of the ventricular system made in encephalograms thus give an impression of the size of the ventricles distended at the expense of compression of sulci, subarachnoid space and possibly of the veins. This distension thus appears to be proportional to the amount of gas injected and the duration of such an injection with possible modifications due to the individual capacity to absorb the CSF and the gas and also of the type of gas used. These observations, however underline that if any conclusions are to be drawn, at least concerning relatively small differences in measurements between different encephalograms, the examinations must be made with a uniform technique. In the present material the technique was as uniform as reasonably possible. Somewhat longer duration of the examination of the patients in the adenoma groups could however not be avoided, as they were, as a rule, examined with tomography. Most of the roentgenograms used for determination of the volume in the present investigation were exposed during the later part of the encephalographic examination, that is 30–40 minutes after the first injection of gas, while the ventricular system was still probably somewhat distended.

No notable variation in the width of the ventricle has been reported after the first half hour after the end of the injection of gas. Not until after 3–24–48 hours have any changes been recorded, and then an increase, most marked in patients with disturbed circulation of the CSF (ROYTT *et coll* 1972). That at least small differences in examination technique have no decisive effect on the ratio found is suggested by the fact that the present control group showed in men an average value of 0.27 of Evans ratio (EVANS 1942) which is in complete agreement with what has been found by ANDERSEN *et coll* (1963) in a normal material of 44 adult men. The widening caused by the gas injection is probably small in judge from the high correlation between the pneumographic and echoencephalographic determination of ventricular size that SJOOGREN *et coll* (1968) found in infants and children in whom the ventricular system is more easily dilated than in adults. PROBYT (1972) has reported that the anterior part of the lateral ventricle diminished in width during the temporal horn filling manoeuvre. The septum-caudate distance decreased 19–23 per cent but the anterior horn span and the body span only about 1–3 per cent. In the present material the measurement as a rule has been taken before the filling of the tem

poral horns as the gas filling afterwards was thought to be insufficient for reliable measurement of relevant distances. The great variation of the septum-caudate distance that can appear could not be detected in the investigation by SJÖGREN et coll (1968) as this distance cannot reliably be determined with echoencephalography. Their correlation was mainly based on body span and width of the third ventricle.

The widths of the grooves cannot be measured exactly because the individual gas filled grooves often vary somewhat in width along their course and they are often superimposed in the roentgenograms, which makes measurement difficult. It may also be difficult to decide which grooves should constitute the majority of the wide and the majority of the narrow grooves respectively. These difficulties are however probably the same in all three groups so that no systematic difference should occur. To eliminate the possibility of bias, another radiologist (Bengt Lindholm) who was unaware of the group to which the various roentgenograms belonged, measured the widths of the grooves in the same way and arrived at largely the same results. In the measurements of the widths of the grooves like the height of the smaller anterior horn the measures from the films were used without correction for the enlargement, because the difference in enlargement between the Lysholm and the Mimer stands in the lateral projection was calculated to be only 1 per cent and because the degree of enlargement is small and is fairly constant since the film is exposed as close as possible to the skull.

Measurements in the ventricular system and of the width of the skull were also done by a further neuroradiologist (Gunnar Fagerberg). No systematic difference in the results between the two observers was found.

Conclusions suggested by results of investigation of parameters capable of influencing ratios and other measurements. Roentgengeometric and technical factors of the examination thus had no significant effect on the results of measurements. The differences in measurements and ratios demonstrated between the three groups (A-N-C) were due to true differences in the width of the ventricular system and of the grooves.

Comments on the results of the factor analysis

The factor analysis (Table 1) somewhat unexpectedly showed significant differences in the effect of the hypophyseal lesion on the left anterior horn but not on the right, in the evaluation of the absolute measurements. The difference decreased somewhat when ratios were evaluated suggesting that the difference was partly due to a variation of enlargement.

however that if the brain were dilated less than normally on injection of gas into the ventricular system, the subarachnoid space and the grooves should be wider and, if anything not be smaller than in controls, where one must expect ordinary compression of the grooves during the encephalographic procedure. Conversely, that the gas filled ventricular system in patients with chromophobe adenoma is wide cannot be explained by a stronger distension by the gas because if it could the gas filled grooves would not be wider than ordinarily.

Measurements of the ventricular system made in encephalograms thus give an impression of the size of the ventricles distended at the expense of compression of sulci subarachnoid space and possibly of the veins. This distension thus appears to be proportional to the amount of gas injected and the duration of such an injection with possible modifications due to the individual capacity to absorb the CSF and the gas and also of the type of gas used. These observations, however underline that if any conclusions are to be drawn, at least concerning relatively small differences in measurements between different encephalograms, the examinations must be made with a uniform technique. In the present material the technique was as uniform as reasonably possible. Somewhat longer duration of the examination of the patients in the adenoma groups could however not be avoided, as they were, as a rule, examined with tomography. Most of the roentgenograms used for determination of the volume in the present investigation were exposed during the later part of the encephalographic examination, that is 30–40 minutes after the first injection of gas, while the ventricular system was still probably somewhat distended.

No notable variation in the width of the ventricle has been reported after the first half hour after the end of the injection of gas. Not until after 3–24–48 hours have any changes been recorded and then an increase, most marked in patients with disturbed circulation of the CSF (ROVIT *et coll* 1972). That at least small differences in examination technique have no decisive effect on the ratio found is suggested by the fact that the present control group showed in men an average value of 0.27 of Evans ratio (EVANS 1942) which is in complete agreement with what has been found by ANDERSEN *et coll* (1963) in a normal material of 44 adult men. The widening caused by the gas injection is probably small to judge from the high correlation between the pneumographic and echoencephalographic determination of ventricular size that SJOOREN *et coll* (1968) found in infants and children in whom the ventricular system is more easily dilated than in adults. PROMET (1972) has reported that the anterior part of the lateral ventricles diminished in width during the temporal horn filling manoeuvre. The septum-caudate distance decreased 19–25 per cent but the anterior horn span and the body span only about 1–3 per cent. In the present material the measurement as a rule has been taken before the filling of the tem

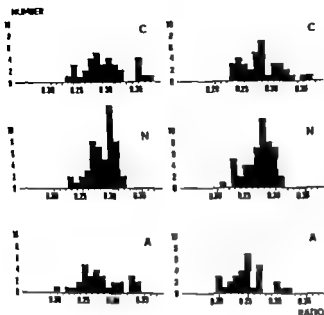


Fig 5 $\frac{1}{2}$ ratio of the ratios in the three groups. Left Ratio for the left anterior horn. Right Ratio for the smaller horn in each patient.

mentioned not more than 1–2 mm. Most of the narrower anterior horns are thus situated on the right side. Elimination of the wider anterior horns on the right side and incorporation of the corresponding narrower horns on the left side thus results in a significant difference ($p < 0.05$) between the three materials. The left anterior horn was smaller in 9 of 30 in the group with acromegaly, in 9 of 52 in the control group and in 11 of 34 with chromophobe adenoma. The proportion of narrower anterior horns emanating from the left side had, on the average, a ratio of 0.243. The corresponding figure for the narrower anterior horns on the right side was 0.246.

In Fig 5 there is a cluster of patients in A and C to the extreme right with the highest ratios. These patients might have had injuries not related to the basic disease, causing a widening of the horns. N is cut off at ratio 0.33 and thus cannot show any cluster. This reduces the difference to A and increases it to C.

The smaller septum caudate distance was evaluated for the same reasons as those given for the anterior horn. This measure and its ratio are closely related to the anterior part of the body and in acromegaly it was significantly smaller ($p < 0.05$).

The third ventricle was narrower in the patients with acromegaly than in the controls. The result of the comparison with patients with chromophobe adenoma is however possibly less reliable because all of the 34 patients with chromophobe adenoma except 4 had a sellar adenoma portion which often deformed the



Fig. 6 Encephalogram of a 30 year old man with acromegaly with typical small ventricular system and fairly narrow grooves

third ventricle. Yet the factor analyses showed no correlation between the occurrence of suprasellar extension and the above difference in width. In 9 of the 30 patients with acromegaly the area of the pituitary adenoma had been irradiated. The third ventricle, at least its anterior lower part, is often also irradiated during such treatment. It is well known that this has an atrophying effect (Wilson et coll. 1972) but the third ventricle was nevertheless narrower in the group with acromegaly than in the other groups.

As for the width of the grooves, differences were found between the groups in this material ($p < 0.01$).

That no significant differences could be found regarding the width of the smallest temporal horn or, in a earlier *t* test, of the sum of the width of the temporal horns may probably be explained by the fact that the measure is too small to show a difference, if any, with the method used.

The height of the fourth ventricle can often be measured with certainty only with the aid of tomography. Otherwise it is not possible to distinguish between the positions of the fastigium and the posterior superior recesses (AMUNDSEN & GRIMSRUD 1966, OBERSON et coll. 1969, CORRALES & GREITZ 1972). Tomography was used only to limited extent in the controls; therefore no certain comparison was possible. In addition, the measured height of the fourth ventricle depends on at which time relative to the injection of the gas the film is exposed (OBERSON et coll. 1969). Such differences may have masked any true differences between the groups.



Fig 7 Encephalogram of 34 year old woman with chromophobe adenoma. Ventricular system and particularly the grooves wider than ordinarily. The measurement of the height of the smaller anterior horn is indicated with broken line.

In summary Patients with acromegaly thus seem to have a relatively smaller ventricular system and on the average, narrower grooves than controls and in these respects they differ still more from patients with chromophobe adenoma. Since an increase in parts of the volume of the cerebral parenchyma or of its entire volume is accompanied by a corresponding reduction of the width of the ventricular system and of the subarachnoid space, the smaller dimensions of the cerebrospinal space in patients with acromegaly means that the volume of the cerebral parenchyma in such patients is increased and conversely decreased in patients with chromophobe adenoma (Figs 6-7).

Discussion

Various explanations may be offered for the brain volume in acromegaly. One might imagine that the acromegalic brain offers greater resistance to ageing processes than in normals. An objection that might be raised against such an assumption, however, is that even in relatively young patients with acromegaly the brain is increased in volume, i.e. before physiologic ageing can be expected.

That a suprasellar part of an adenoma should explain the general increase in volume is not likely. First because the factor analysis did not show any differences between cases with and without an extrasellar part, and secondly because patients with chromophobe adenoma often had a significantly larger suprasellar part and nevertheless a wider CSF space than the patients with acromegaly.

In Cushing's disease which is associated with a high incidence of cortical

atrophy there is a catabolic metabolism of proteins leading to a negative nitrogen balance. Acromegaly can be regarded as a counterpole to Cushing's disease, because in acromegaly there is a marked anabolic metabolism which according to MOMOSE et coll (1971) may be related to the low incidence of cortical atrophy in acromegaly. No correlation could be found between the duration of the disease and the width of the intracranial CSF space in the group with acromegaly or the group with chromophobe adenoma. No analysis of the correlation between the level of the growth hormone and the dimensions of the intracranial CSF space was possible because the number of cases where such hormone analysis had been performed was too small.

That the soft tissues increase in volume in acromegaly such as in the hands and feet (LANG & BLESSER 1961 STEINBACH & RUSSEL 1964 KHO et coll 1970) as well as in the epipharynx, as was apparent from the present investigation ($p < 0.01$) and that the viscera increase in size (splanchnomegaly) is believed to be due partly to an increased deposition of acid mucopolysaccharides and chondroitin sulphate in the collagen fibrils in the connective tissue, and partly to an increase in size and number of the cells. Human growth hormone (HGH) induces the production of somatomedin which is the actual growth promoting factor (HALL 1972). But the brain contains no connective tissue, for which reason it remains to be considered whether the increased volume of the cerebral parenchyma in acromegaly might not be due to an effect of the growth hormone on the brain cells. With conventional histologic methods no changes however have been demonstrated in the brain in acromegaly.

The increase in brain volume is moderate and probably occurs slowly and is not so marked as to cause papilloedema. FINLAY & MACDONALD (1954) found at autopsy in three acromegalic male patients brain weights of 1 460 g (59 yrs), 1 230 g (68 yrs) and 1 570 g (40 yrs). Normal brain weight is considered to be 1 250 g. CUSHING & DAVIDOFF (1927) in their four autopsied cases reported a brain weight only in one (1 325 g, 52 yrs).

A very common symptom of acromegaly, a severe persistent headache, might, however be caused by the increase in volume of the cerebral parenchyma. This headache has been assumed to be due to the expansion of the pituitary adenoma in the sphenoidal body and stretching of the dura, but no clear correlation appears to be demonstrable between the enlargement of the sella turcica and the frequency and severity of headache. With encephalography demonstrated probable increase of brain parenchyma in an acromegalic patient might contribute to the indication for hypophysectomy or radiation therapy to relieve headache and to prevent pressure atrophy of the brain. Hitherto no systematic investigations have been done suggesting that also the brain is involved in the general organomegaly which occurs in acromegaly. HATAKI & GRITZ (1972)

examined only the large vessel trunks, the carotid in the region of the neck and the proximal intracranial arteries which run from the surface of the brain in the crista and which probably not contribute considerably to the increase in volume of the cerebral parenchyma.

Investigations of number and size of the brain cells are required to explain the increased brain volume in acromegaly.

Addendum in proof

Since the preparation of this communication UTHVETZ et coll (1974) has partly purified a human hormone that has been called somatomedin B to distinguish it from the somatomedin A isolated by HALL (1972). WESTERMARK et coll (1974) have shown that somatomedin B stimulates the synthesis of DNA in human glia cells in tissue culture. Somatomedin A and B are both human growth hormone (HGH) dependent. An increased amount of glia may thus hypothetically contribute to the increased volume of the cerebral parenchyma in acromegaly.

Acknowledgement

The statistical analysis was carried out by M. Lars Lindvall, lecturer in statistics, University of Linköping, Linköping, Sweden.

SUMMARY

In 30 acromegalic patients the brain volume was investigated from encephalographic measurements. A comparison was made with 34 patients with chromophobe adenoma and a control group of 52 patients. With statistical factor analysis it was found that patients with acromegaly had a significantly increased volume of the cerebral parenchyma and in patients with chromophobe adenoma it was somewhat decreased. The etiology and implications of these observations are discussed.

ZUSAMMENFASSUNG

Bei 30 Patienten mit Akromegalie wurde aus encephalographischen Messungen das Gehirnvolumen bestimmt. Ein Vergleich mit 34 Patienten mit einem chromophoben Adenom und mit einer Kontrollgruppe von 52 Patienten wurde gemacht. Mittels statistischer Faktor-Analyse wurde festgestellt, dass Patienten mit Akromegalie ein signifikant höheres Volumen des cerebralen Parenchyms hatten während das von Patienten mit einem chromophoben Adenom etwas geringer war. Die Ätiologie und Bedeutung dieser Beobachtungen werden besprochen.

RÉSUMÉ

L'auteur détermine le volume du cerveau à partir de mesures encephalographiques chez 30 acromégales. Il a fait une comparaison avec le volume cérébral de 34 malades atteints d'adénome chromophobe et d'un groupe de 52 témoins. L'analyse statistique a montré que le volume des acromégales est significativement augmenté et qu'il est un peu diminué chez les malades atteints d'adénome chromophobe. L'auteur étudie l'étiologie et les implications des observations.

REFERENCES

- AMUNDSEN P and GRIMHOLD O K. Height of fourth ventricle in normal encephalograms. *Acta radiol Diagnost* 4 (1966) 257
- ANDERSEN F, LARSEN J V og JACOBSEN H H. Atrophia cerebri (In Danish) *Ugeskr Læg* 125 (1963) 86
- BECK K J and LÖNNYU A. Ventricular size in relation to cranial size. *Acta radiol Diagnost* 4 (1966) 65
- BRUYN G W. Pneumoencephalography in the diagnosis of cerebral atrophy. A quantitative study. H J Sm III Utrecht 1959
- BURKHENDE H J and DALLMANN H. The ventricular span in cerebral pneumoencephalography. *Amer J Roentgenol* 90 (1963) 1176
- BUSE E W, BARNES R H, FRIEDMAN E L and KELTY E J. Psychological functioning of aged individuals with normal and abnormal electroencephalograms. *J Nerv Ment Dis* 124 (1956) 13
- and ORNSTEIN W D. Significance of focal electroencephalographic changes in the elderly. *Postgrad Med* 34 (1963) 179
- COBRALLES M and GRITZ T. Fourth ventricle. I. A morphologic and radiologic investigation of the normal anatomy. *Acta radiol Diagnost* 12 (1972) 115
- CURRINO J and DAVIDOFF L M. The pathologic findings in four autopsied cases of acromegaly with a discussion of their significance. Rockefeller Institute for Medical Research (1927) Monograph 22
- ENOKET A and SARAASTAD E. Methods of measurement in encephalography. *Neurology* 14 (1964) 381
- EVANS JR W A. An encephalographic ratio for estimating ventricular enlargement and cerebral atrophy. *Arch Neurol Psychiat* 47 (1942) 931
- An encephalographic ratio for estimating the size of the cerebral ventricles. Further experience with serial observations. *Amer J Dis Child* 64 (1942) 820
- FINDLAY J M and MACDONALD R I. Acromegaly. *Canad med Ass J* 71 (1954) 345
- FETTERELL G and LINDGREN E. Mimer I. *Acta radiol* 53 (1959) 209
- GRITZ T, GREPE A and HOLMSTROM L. Mimer III and rotating chair. *Acta radiol Diagnost* 7 (1968) 543
- GOLANITZ G. Über das normale Encephalogramm im Kindesalter. *Nervenzentr* 22 (1951) 101
- HALL K. Human somatomedin. Determination, occurrence, biological activity and purification. *Acta endocr (Aab)* (1972) Suppl No 163
- HATAM A and GRITZ T. Ectasia of cerebral arteries in acromegaly. *Acta radiol Diagnost* 12 (1972) 410
- JØGENSEN D H and GUSTAFSSON L. Regional cerebral blood flow in organic dementia with early onset. *Acta neurol scand* 46 (1970) 42
- JIROUT J. Changes in the size of the subarachnoid spaces after the insufflation of air. *Acta radiol* 46 (1956) 81
- KJELDSEN P A. Ventriklenes størrelsesforhold i anatomisk normale hjerter fra voksne mennesker (In Danish) *Andelsbøgertrykkeriet Odense* 1958
- KUJO K M, WRIGHT A D and DOYLE F H. Heel pad thickness in acromegaly. *Brit J Radiol* 43 (1970) 119
- LANG E K and BENSLER W T. The roentgenologic features of acromegaly. *Amer J Roentgenol* 86 (1961) 321
- LARSEN H and LINDGREN E. Encephalographic examinations of 125 institutional epileptics. *Acta psychiat scand* 15 (1940) 337

- LAURER H. Das Pneumoencephalogramm Messverfahren bei Erwachsenen Johan Ambrosius Barth München 1965
- LE MAY M. Changes in ventricular size during and after pneumoencephalography *Radiology* 88 (1967) 57
- LEWIS T. POTTS D. G. and DICK M. D. F. Changes in the ventricular size during fractional pneumoencephalography *Radiology* 104 (1972) 583
- LINDQVIST E. Some aspects on the technique of encephalography *Acta radiol* 31 (1949) 161
— Encephalography in cerebral atrophy *Acta radiol* 35 (1951) 277
- LOOF H. Size and development of the cerebral ventricular system in childhood *Acta radiol Diagnost* 7 (1968) 385
- MONSON J. J., JYLLBERG R. N. and KLINMAN B. High incidence of cortical atrophy of the cerebral and cerebellar hemispheres in Cushing disease *Radiology* 99 (1971) 341
- MOORE B. Acromegaly and contrasting conditions *Amer J Roentgenol* 68 (1952) 565
- OSSEKOV R., CANDARJIS G. and RAAD N. Height of fourth ventricle *Acta radiol Diagnost* 9 (1969) 193
- OSTAARD A. Changes in ventricular size during pneumoencephalography *Neuroradiology* 3 (1971) 8
- PROBST F. P. Rapid changes in the volume of the lateral ventricles at encephalography *Acta radiol Diagnost* 12 (1972) 757
- RADSTROM C. Encephalogrammet vid akromegali (In Swedish) Paper read at the meeting of the Swedish Society of Medical Radiology, Linköping 1972
- ROVIT R. L., SCHNEIDER M. M., ORTIZ B. and BRINLEY R. V. Progression of ventricular dilatation following pneumoencephalography: A radiological sign of conculthydrocephalus *J Neurosurg* 36 (1972) 50
- SCHATZKI R., BAXTER D. H. and THOLAND C. E. Second day encephalography with particular reference to the size of the ventricles *New Engl J Med* 236 (1947) 419
- SCHNEIDERMAN O. Einführung in die Encephalographie 2 Aufl Georg Thieme Stuttgart 1952
- SYGÖREN I., BERGSTRÖM K. and LOOF H. Echoencephalography in infants and children: Comparison with cerebral pneumography in measuring ventricular size *Acta radiol* (1968) Suppl No 278
- STERNACH H. L. and RUSSEL W. Measurement of the heel pad as an aid to diagnosis of acromegaly *Radiology* 82 (1964) 418
- THIEBAUT F., WACKENHEIM A. and ROUSSE C. Pneumostratigraphie sagittale médiane de la fosse postérieure *Acta radiol Diagnost* 1 (1963) 638
- TORKILSEN A. An analysis of shadows seen in pneumograms of cerebral ventricles *Acta psychiatr scand* 9 (1934) 465
- THOLAND C. E., BAXTER D. H. and SCHATZKI P. Observations on encephalographic findings in cerebral trauma *J Clin Invest* (1946) 390
- UTTER L., WESTERMARK L. and W. TEROF A. Purification of somatomedin from human plasma stimulating DNA synthesis in human glioblastoma cells To be published in *J Cell Physiol*
- WESTERMARK B., WESTERMARK L. and UTTER L. Isolation of DNA synthesis of serum dependent and topoisomerase containing somatomedin from human plasma To be published in *J Cell Physiol*
- WILSON G. H., BYFELT L. and HANAFER W. N. Atrophy following radiation therapy for acromegaly *Acta radiol Ther Phys Biol* 11 (1972) 361

CORTICAL BONE MASS IN ACROMEGALY

D G IAKOS, A NTALLES, CH VELENTZAS and P KATSICHTIS

The prevailing opinion that acromegaly is often associated with osteoporosis (ALBRIGHT & REIFENSTEIN 1948, BELL & BARTTER 1967, DAUGHADAY 1968, SERRE et coll 1970) needs, according to DOYLE (1967), considerable qualification since it is based on visual qualitative estimation of the mineral content of bone in roentgen films which generally is considered inadequate for the estimation of bone mass (LAHEMAN 1955, BLAND et coll 1969). Furthermore, recent skeletal surveys of acromegaly by NADARAJAH et coll (1968) and JULIANI et coll (1970) failed to confirm the older reports in agreement with the results of the two quantitative estimations of bone mass in acromegaly available so far. Thus the mineral content of the distal third of the ulna of 53 acromegalics, as investigated by densitometry with roentgen films, has been classed as normal by DOYLE (1967) while RIGGS et coll (1972) gave increased values obtained by the method of CAMERON & SORENSON (1963). While DOYLE (1967) had not been able to find clear cut vertebral osteoporosis in his 54 patients, RIGGS et coll (1972) described such changes in 11 of their 28 patients, with small but definite anterior wedge compression in 2 of these 11 patients.



Fig 1 Schematic representation of the measurements of the left second metacarpal L = length $a-b$ = external diameter (D) d = internal diameter $CT_1 + CT_2$ = cortical thickness (CT)

Osteoporosis in acromegaly is of practical as well as of theoretic interest in the sense that osteopenia seems to be an unexpected phenomenon in a condition leading to increased skeletal growth, as in acromegalic gigantism. A re-evaluation was therefore considered worthwhile by measurements of the cortical bone mass, using as a parameter the results of morphometric observations of the left second metacarpal bone—a technique generally available.

Material and Method The material consisted of 65 acromegalics: 27 males aged 17 to 59 and 38 females aged 19 to 67 years. Morphometric observations of the left second metacarpal bone were made in conventional roentgenograms obtained at a FFD of 80 cm. A miniature with a vernier (Taschenmeßlupe TM14 C Zeiss) produced the following measurements in each subject (Fig 1): a) total length (L), b) external diameter (D) ($a-b$), c) internal diameter (d) and d) cortical thickness ($CT = CT_1 + CT_2$). D , d and CT being measured at the middle of the bone.

The Extent Score index was calculated from the formula

$$\frac{D-d}{L-D}$$

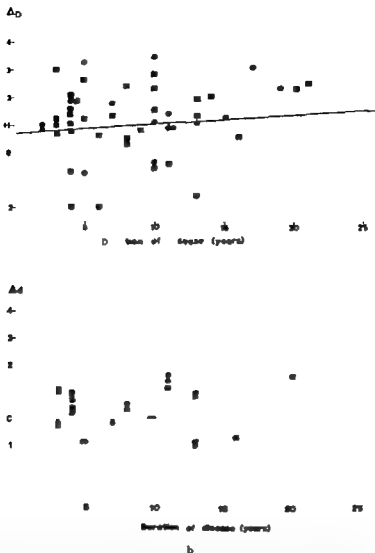


Fig. 2 Relationship between duration of disease and normalized difference from normal of a) the external ($=0.584$, $p < 0.01$, $Y = 0.69 + 0.0281x$) and b) the internal ($= -0.297$, $p < 0.02$, $Y = -0.0165x$) diameter of the left second metacarpal bone (ΔD) in 65 acromegalic patients: \circ males \blacksquare females.

The data of acromegalics of the present investigation were compared to those obtained by the same technique in a group of 381 male and 1 522 female control Greek subjects, aged 16 to 90 years, reported elsewhere (IAKOS *et al.* 1972).

The level of fasting plasma growth hormone was measured in 40 of the 65 patients by a double antibody radioimmune assay method based on that described

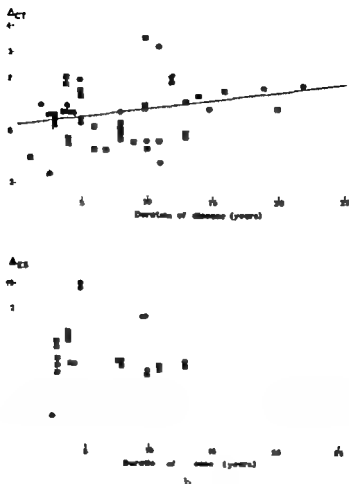
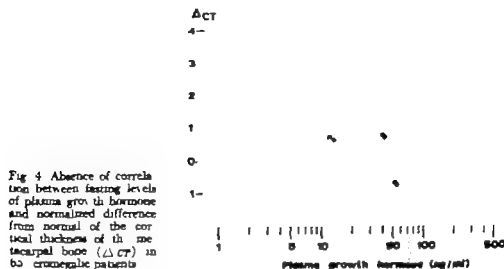


Fig 3 Relationship between duration of disease and normalized difference from normal of a) the cortical thickness of the metacarpal bone (ΔCr) ($r = 0.858$ $p < 0.001$) $y = 0.064 + 0.0546x$ and b) the Extremity Score index of the metacarpal bone (ΔES) in 63 acromegalic patients ● males ■ females

for insulin by MORGAN & LAZAROW (1963) as modified by JACKSON et al (1968) and with the standard and optimized HGH (1 I) commercially available as a kit from CEA CEN SORIN.

The statistical analysis of the results was performed by standard techniques (SVEDJÖR & COCHRAN 1971).



Results

The change in cortical bone mass with age and the differences between the two series (GARN 1970, NEWTON, JOHN & MORGAN 1970, VIRTAMA & HELELA 1969, IAKOS *et al.* 1972) indicated that the values of the acromegalics could be grouped together (Figs 2 to 4) only after being normalized by the formula

$$\Delta = \frac{x - \bar{x}}{SD}$$

where Δ = normalized difference

x = true value

\bar{x} = mean normal value for corresponding sex and age and

SD = standard deviation for the normal population

The external diameter (D) of the metacarpal was larger than that of the control group in 49 (or 75 per cent) of the acromegalic patients ($\bar{x} = 16.754$, $p < 0.001$), the mean Δ for D being 0.94 ± 0.163 , a value significantly larger than zero ($p < 0.001$) (Fig. 2a). (All \pm values represent the standard error of the mean unless stated otherwise.) A significant positive linear correlation ($r = 0.384$, $p < 0.01$) between Δ_D and duration of the disease was thus evident.

The internal diameter (d) of the acromegaly patients (Fig. 2b) was not different from that of the controls, the normalized difference for d (Δ_d) being positive in 39 (or 61 per cent) and negative in 25 (or 39 per cent) of the 63 acromegaly patients ($\bar{x} = 3.06$, $p > 0.05$). The mean Δ_d was 0.21 ± 0.124 , a value not significantly different from zero ($p > 0.05$). As evident from the significant ($p < 0.02$) negative linear correlation ($r = -0.97$) of the values in figure 2, Δ_d decreased with an advancing duration of acromegaly.

As a result of the increase in the external diameter with the internal diameter remaining practically unchanged the cortical thickness was significantly greater in acromegaly (Fig 3 c) of the 63 patients involved 48 (or 74 per cent) had values above those of the control group while these were smaller in 17 (or 26 per cent) ($\chi^2 = 14.785$ $p < 0.001$) the mean difference from the normal subjects (Δ_{CT}) being 0.75 ± 0.141 ($p < 0.001$).

Because of the advancing increase in external diameter (Fig 2 a) and decrease in the internal diameter (Fig 2 b) with the duration of the disease, cortical thickness also increased progressively as indicated by the strong positive linear correlation ($r = 0.858$ $p < 0.001$) between Δ_{CT} and duration of the disease (Fig 3 a). That the increase in cortical thickness with duration of the disease was not due to an overall increase in the size of the metacarpal was demonstrated by the index proposed by ELLROY SMITH et coll (1969) by which the cortical thickness is normalized for the size of the bone. The normalized difference for the ELLROY SMITH index (Δ_{ES}) was positive in 42 (or 65 per cent) and negative in 23 (or 35 per cent) acromegaly patients ($\chi^2 = 13.087$ $p < 0.01$) with a mean Δ_{ES} value of 0.62 ± 0.171 i.e. one significantly different from zero ($p < 0.001$) (Fig 3 b).

Sex had no influence on the changes of cortical bone mass in acromegaly (Figs 2, 3). The activity of the disease at the time of the examination as estimated from the fasting plasma growth hormone level, was also of no significance on the changes in cortical bone mass observed (Fig 4).

Discussion

Morphometric observations on roentgenograms of the metacarpal bones for the assessment of cortical bone mass introduced by VIRTAMA & MAHOVEN (1960) and BARNETT & NORDA (1960) is now well established (VIRTAMA & HELELA 1969 GARM et coll 1971). The results obtained by this simple and generally available technique compare well with those by other more complicated procedures (MAZEWSKI et coll 1970) and a high degree of correlation exists between the findings from the metacarpals and those from other long bones of the body (HELELA & VIRTAMA 1969). Although measurements of the cortex of the latter may also be used (MERFIS 1969 CAMERON 1970) the left second metacarpal bone was selected for the present work since this was the only bone for which values for a large group of healthy Greek subjects were available (IKKOS et coll 1972).

The necessary limitation of the observations to a single bone may raise doubts as to whether the changes in the metacarpals in acromegaly may be used as a parameter of similar changes of the whole cortex. Examination of the films of

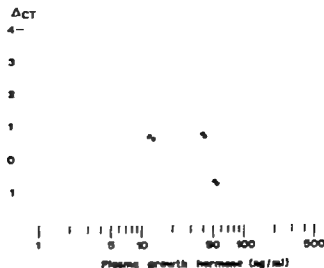


Fig. 4. Absence of correlation between fasting levels of plasma growth hormone and normalized difference from normal of the cortical thickness of the metacarpal bone (ΔCT) in 65 acromegalic patients.

Results

The change in cortical bone mass with age and the differences between the two series (GARN 1970; NEWTON, JOHN & MORGAN 1970; VIRTAMA & HELELA 1969; IKAOS *et al.* 1972) indicated that the values of the acromegalics could be grouped together (Figs 2 to 4) only after being normalized by the formula

$$\Delta = \frac{x - \bar{x}}{SD}$$

where Δ = normalized difference

x = true value

\bar{x} = mean normal value for corresponding sex and age and

SD = standard deviation for the normal population

The external diameter (D) of the metacarpal was larger than that of the control group in 49 (or 75 per cent) of the acromegalic patients ($\lambda = 16.754$, $p < 0.001$) the mean Δ for D being 0.94 ± 0.163 , a value significantly larger than zero ($p < 0.001$) (Fig. 2a). (All \pm values represent the standard error of the mean unless stated otherwise.) A significant, positive linear correlation ($r = 0.384$, $p < 0.01$) between Δ_D and duration of the disease was thus evident.

The internal diameter (d) of the acromegaly patients (Fig. 2b) was not different from that of the controls, the normalized difference for d (Δ_d) being positive in 39 (or 61 per cent) and negative in 25 (or 39 per cent) of the 65 acromegaly patients ($\lambda = 3.06$, $p > 0.05$). The mean Δ_d was 0.21 ± 0.124 , a value not significantly different from zero ($p > 0.05$). As evident from the significant ($p < 0.02$) negative linear correlation ($r = -0.297$) of the values in figure 2, Δ_d decreased with an advancing duration of acromegaly.

modelling—and subperiosteal bone formation—are more active in acromegaly than in normal subjects

It should be mentioned that in normal subjects the internal diameter also increases progressively with age and that after middle age this increase largely exceeds that of the external diameter leading to the thinning of cortical bone so characteristic of senile osteoporosis (VIRTAMA & HELELA 1969 GARN 1970 NEWTON JOHN & MORGAN 1970 CAMEROV 1970 IAAOS *et coll* 1972) The fact that the difference between the true values and those expected for sex and age for the internal diameter of the acromegaly patients (Δ_d) became smaller with the duration of the disease (Fig 2 b) suggests progressive slowing down in the normally occurring bone resorption. It should be pointed out, however, that the slowing down in the bone resorption as acromegaly progresses does not necessarily mean a decrease in the absolute rate: this may represent a decrease in the bone resorption relative to the increased new subperiosteal bone deposition, processes that are normally coupled together.

The present suggestions as to the mechanism of the increase in the cortical bone mass in acromegaly are in good agreement with other observations. Thus periosteal new bone deposition in the short and long tubular bones although not striking, is a well known phenomenon in acromegaly. It is similar to the marginal subperiosteal formation of new bone of the vertebrae which together with the increase in the size of discs—secondary to marginal subperichondrial new formation of cartilage—leads to a squatly shape of the bodies: this change

has usually been interpreted as being due to a decrease in the height of the bodies whereas actually the change in proportion is the result of widening of the bodies (JAFFE 1972).

Tetracycline labelling examinations of the bones of 2 acromegaly patients have revealed an increase in the overall bone formation rate of the active case (RAMSER *et coll* 1966) and a normal value in the other inactive case (VILLA NUOVA *et coll* 1966). ROELFPERMA *et coll* (1971) demonstrated with micro-radiography an increase in the average volume of trabecular bone as well as an activation of both formation and resorption of bone in the cortical and sub-cortical regions with a slight increase in the trabecular bone formation. RHOOS *et coll* (1972) by the same technique reported that forming surfaces exceeded resorbing surfaces in cortical bone in acromegaly and that both were increased above normal: an increase positively correlated to the serum growth hormone level. This accelerated bone remodelling led to increased bone width and an increased or normal cortex. Finally IARRIX & HEANEY (1969) have observed a marked increase in the rate of formation of cortical bone and a net increase in the bone mass of six adult dogs given growth hormone for six months.

other long bones of acromegaly patients—with changes similar to those in the metacarpals—indicate that the results from measurements of the metacarpals are useful parameters for total cortical changes in this condition.

The possibility that the increase in cortical thickness in acromegaly may represent an increase in bone volume without an increase in bone mass can be excluded since measurements by the photon absorption technique of CAMEROV & SORENSON (1963) of the metacarpals of 10 acromegalic subjects gave increased values (unpublished observations).

The opinion that the results of the present investigation based on measurements of the second metacarpal bone are valid for the whole cortical bone mass is strongly supported by the aforementioned results of ROOS *et coll* (1972). These authors reported increased absorption of roentgen rays of the middle of the radius in 20 acromegalics while ALOIA *et coll* (1972) writing on total body calcium of acromegalic patients as measured by neutron activation analysis *in vivo*, stated that the values for the acromegalics varied between 88.8 and 122.5 per cent of those expected for normal subjects on a height basis, with 8 of the 10 values over 109.1 per cent. The increase in cortical bone mass now given is in agreement with the experimental results of HARRIS & HEANEY (1969) in six dogs that had an increase in bone mass after 8 months treatment with growth hormone.

The present findings that both cortical thickness and cortical surface area normalized for bone size (EXTON SMITH index) proved to be significantly larger in acromegaly than in normal subjects demonstrate that cortical bone mass is significantly increased in acromegaly. The fact that the increase in cortical thickness of the acromegalics resulted from an increase in the external diameter while the internal diameter was normal permits indirect evaluation of the mechanisms responsible for the increase in cortical bone mass in acromegaly. Since an increase in the external diameter signifies accelerated subperiosteal bone formation and since the normal size of the internal diameter indicates normal bone resorption, acromegaly should be classified according to GARN *et coll* (1971) as a condition characterized by increased bone formation, normal bone loss.

It should be mentioned that the external diameter increases directly with height up to the completion of bodily development and thereafter slowly to old age, as a result of skeletal development initially and then constant bone remodelling (SMITH & WALKER 1964; BONYARD 1968; VIRTAMA & HELELÄ 1969; GARN 1970; NEWTON JOHN & MORGAN 1970; IKKOS *et coll* 1972). The findings that the difference between the true values and those expected for sex and age for the external diameter of acromegaly patients (Δ_D) became more positive with the duration of the disease (Fig. 2a) demonstrate that bone re-

- and SORINSON J. Measurement of bone mineral in vivo. An improved method. *Science* 142 (1963) 230
- DALGHADAY W. H. *Adenohypophysis I*. Textbook of endocrinology p. 27. W. H. Saunders Company, Philadelphia, London, Toronto 1968
- DOYLE F. H. Radiology of the skeleton in endocrine diseases. *Proc. roy. Soc. B* 60 (1967) 1131
- EXTON SMITH A. V., MILLARD P. H., PATTER P. R. and WITZLER E. F. Method for measuring quantity of bone. *Lancet* 2 (1969) 1153
- GARA S. M. The earlier gain and the later loss of cortical bone. Charles C. Thomas Publisher, Springfield 1970
- , FORNABEKI A. K. and NADY J. M. Bone measurement in the differential diagnosis of osteopenia and osteoporosis. *Radiology* 100 (1971) 509
- HARRIS W. H. and HENKLEY R. P. Effect of growth hormone on skeletal mass in adult dogs. *Nature* 223 (1969) 403
- HIELELA T. and VIRTAMA P. Cortical thickness of long bones in different age groups. *Symposium Osseum* p. 238. London 1970
- IKKOS D. G., VALENTZAS CH., KATSOCHIS P., NYALLES K., STERGIOS L. and SKORDALAKIS E. Effect of age on bone mass of the greek population aged 15–90 years: morphometric observations. *Iatriki* 21 (1972) 287
- JACKSON D., GRANT D. B. and CLAYTON B. E. A simple oral test of growth hormone secretion in children. *Lancet* 2 (1968) 373
- JAFFE H. L. *Metabolic, degenerative and inflammatory diseases of bones and joints*. Urban und Schwarzenberg, München—Berlin—Wien 1972
- JULIANKI G., AGATI G. and MOLINATTI G. M. Skeletal alterations in acromegaly. *Symposium Osseum* p. 173. London 1970
- LACHMAN E. Osteoporosis: The potentials and limitations of its roentgenologic diagnosis. *Amer. J. Roentgenol.* 74 (1953) 712
- MAEDER R. B., CASERSON J. R. and SORINSON J. A. A comparison of radiological methods for determining bone mineral content. *Proceedings of Bone Measurement Conference*. United States Atomic Energy Commission 1970
- MERX H. E. Cortical bone mineral density versus cortical thickness in the diagnosis of osteoporosis. A roentgenologic densitometric study. *J. Amer. Geriatr. Soc.* 17 (1969) 120
- MORGAN G. P. and LAZAROW A. Immunosensitivity of insulin. Two antibody systems. *Diabetes* 10 (1963) 115
- NADARAJAN A., HARTDOO M., REDFERN B., THALAMANDOS V., WRIGHT A. H., JOPLIN G. F. and RUSSELL FRASER T. Calcium metabolism in acromegaly. *Brit. med. J.* 4 (1968) 797
- NEWTON JOHN H. F. and MORGAN D. B. The loss of bone with age, osteoporosis and fractures. *Clin. Orthop.* 71 (1970) 229
- RAMER J. R., FROST H. M. and SMITH R. Tetracycline based measurement of the tissue and cell dynamics in rib of 25-year-old man with active acromegaly. *Clin. Orthop.* 49 (1966) 169
- ROOS B. L., RANDALL R. V., WAINER H. W., JOWETT J., KELLY P. J. and SINGH M. The nature of metabolic bone disorder in acromegaly. *J. Clin. Endocr.* 34 (1972) 94
- ROSLERMAN F., VAN DER SLUIS A. K. J. and BAKKER D. Quantitation of bone and bone turnover in biopsy specimens from the iliac crest in acromegaly. *Israel J. med. Sci.* 7 (1971) 498
- SERRE H., SEMOV L. et SAVAL J. Les manifestations ostéoarticulaires de l'acromégalie. *Sem. Hop. Paris* 46 (1970) 1603

- SMITH R W JR and WALKER R R Femoral expansion in aging women implications for osteoporosis and fractures *Science* 145 (1964) 156
- SYEDICOR G W and COCHRAN W G *Statistical Methods* The Iowa State University Press Ames Iowa 1971
- VILLANUEVA A R ILWICKI L DUNCAN H and FROST H M Bone and cell dynamics in the osteoporosis a review of measurements by tetracycline bone labeling *Clin Orthop* 49 (1966) 135
- VIRTAVA P and HELELA T Radiographic measurements of cortical bone Variations in a normal population between 1 and 90 years of age *Acta radiol* (1969) Suppl No 293
- and MAHONEN H Thickness of the cortical layer as an estimate of mineral content of human finger bones *Brit J Radiol* 33 (1960) 60

MOYA MOYA VESSELS COLLATERAL ARTERIES OF THE BASAL GANGLIA Malignant occlusion of the anterior cerebral arteries

KLAS ROSENGREN

The cerebrum is protected from ischaemia by several types of collaterals particularly the circle of Willis, the collaterals from the external carotid arteries including the transdural communications (a rete mirabile, MOUTT & TAVERAS 1957) and the leptomeningeal (pial) anastomosis (LANNER & ROSENGREN 1964).

Obliterating arterial disease is much more common in Japan than in the United States or Europe. TAKEUCHI (1961) reported two cases of carotid arterial stenosis and abnormal net like blood vessels at the base of the brain. The appearances of the blood vessels suggested the term *moya moya* to indicate the resemblance of the many small vessels to a hazy puff of cigarette smoke (*moya moya* in Japanese). SUZUKI & TAKAKU (1969) considered the abnormal vessels at the base of the brain and the various types of carotid stenosis as one and parcel of a particular disease. An investigation of 20 patients showed several stages. The condition apparently starts with a narrowing of the intracranial part of the carotid vessel and the *moya moya* vessels appear gradually to disappear again as other collateral pathways become established. The *moya*

Submitted for publication 23 February 1973

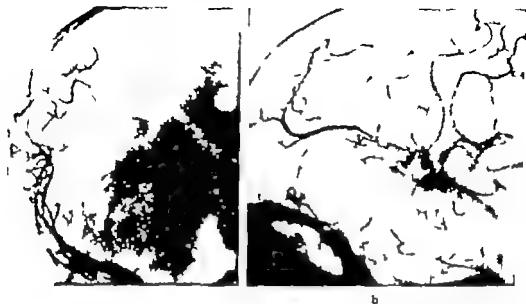


Fig 1 Angiography of the right carotid artery a) A.p. b) Lateral. Large midline basal tumour with lateral displacement of hypertrophied arteries of the basal ganglia. Part of the pericallosal artery is revealed by the collateral function of these arteries. Unfilled anterior cerebral artery.

moya vessels were evident in patients of all ages up to 50 years, although 12 out of 20 were under the age of 20. These vessels were originally considered to be present only in the Japanese race and only few reports of vascular changes of the moya moya type have been published in Europe. GERLACH *et coll.* (1967) have presented a case with a vascular structure similar to the moya moya. Clinical information was absent and the legend to the figure read merely capillary angiectasis. A similar case was published by KRAVENBUIL & YAŞARÖL (1965) who also termed the appearance capillary telangiectasis and provided little further information. TAVERAS (1969) however reported 10 cases, 6 of them collected from various parts of the United States, all with multiple progressive intracranial occlusions. Six children in this series had extensive networks of vessels at the base of the brain.

Case report

Boy, aged 4, was admitted with a possible intracranial tumour, no hereditary diseases recorded. Birth and development were quite normal in the age of one when he started to have concomitant strabismus that was impossible to treat owing to almost total blindness in the left eye; no attempt was made to examine the cause. The present condition started in connection with a respiratory infection with marked fatigue and night headache. He also

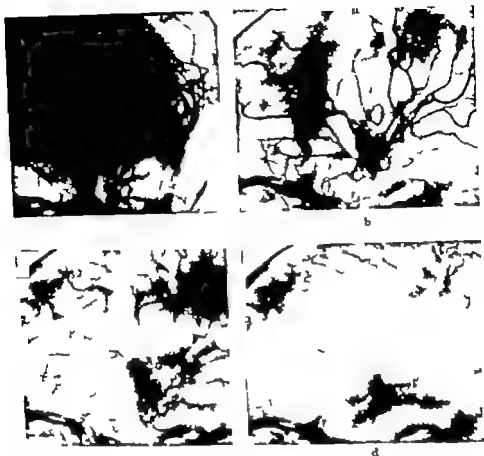


Fig. 2 Angiography of the left carotid artery. a) b) Arterial phase. c) Late arterial phase. d) Precapillary phase. Many almost parallel arteries extend from the base of the skull around and into the basal mass; most are regular but late in the arterial phase become gradually hairy—the moya moya appearance; some retro branches from the narrow and stretched right anterior cerebral artery.

had some difficulty with balance and weakness of the left leg. Lumbar puncture revealed high pressure of the cerebrospinal fluid. The Babinski sign was positive bilaterally and the patient had spastic reflexes in the left arm and leg.

The skull was wider than normal with diastasis of the sutures of 3 to 4 mm; the domum sellae was almost completely missing. No intracranial calcifications were evident. Angiography of the internal carotid artery revealed large expansive mass arising from the base of the skull. Neither the left nor the right anterior cerebral artery was normal in appearance. The right anterior cerebral artery was absent and the left was narrow. Several straight and arched arteries, probably peritrophic arteries of the basal ganglia, from the basal structures (Figs 1, 2). Some of the branches of the right peritrophic artery were filled via the abnormal arteries (Fig. 1). Ventriculography indicated that the

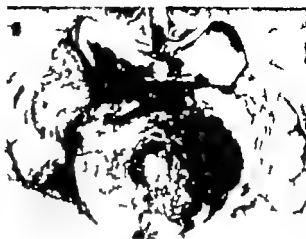


Fig 3 Postmortem examination. The tumour (most with symmetric extension on both sides of the midline) surrounds the third ventricle. A postoperative haematoma lies to the left of the mass.

well outlined with rounded contours bulging into both lateral ventricles. Craniotomy and extirpation of a large left solid tumour was performed. The mass was growing into the left hemisphere partly adherent to the base of the skull and sella turcica. It was well demarcated and at least in its upper part covered with ependyma; the inferior part was hard and attached to the left lesser wing of the sphenoid and the anterior clinoid process. The tumour indented the posterior part of the sphenoid platum. During the operation the mass gave the impression of being a meningioma. The left anterior cerebral artery was stretched narrow and deeply buried in a groove in the lateral aspect of the mass. The left optic nerve was impossible to identify; the right was normal in appearance. The tumour was inoperable. Two days after the craniotomy the patient died of repeated gastrointestinal haemorrhage.

Postmortem examination revealed a large well outlined tumour measuring 4 cm \times 4 cm \times 5 cm in the midline with extension on both sides and invading the structures around the third ventricle (Fig 3). Microscopic examination disclosed a typical spongioblastoma polare. The left anterior cerebral artery was narrowed and stretched along the surface of the tumour; the right anterior cerebral artery was not identified. The left optic nerve was absent and the observations from the preceding operation as to the appearance of the base of the skull were verified. The many narrow arteries were not evident proximally because of blood clots and neoplasm. Several thin walled branches were present more distally at the medial surface of the left hemisphere. Microscopic examination disclosed a large number of meandering arterial vessels of various diameters but with generally thickened internal elastica which however in many places was absent (Fig 4). The vessels described were at a distance from any kind of infiltration.

Discussion

The many fine parallel arteries appearing at the angiography bore no resemblance to tumour vessels. These arteries built up a collateral flow and above the level of the tumour filled the displaced and interrupted right pericallosal artery.



Fig 4 Microscopy of the many narrow arteries arranged in a parallel fashion and extending into the cerebral parenchyma from the base of the skull. No malignant tissue.

(Fig 1) Such transformation into a normal artery never occurs in ordinary tumour vessels. The arteries described bear some resemblance to moya moya arteries especially in the late arterial phase (Fig 2 c, d).

The occlusions of the right and left anterior cerebral arteries were not caused by primary arterial disease but rather by compression from outside over a long period of time. This compression had in all probability commenced as early as three years before admission. The patient was one year old when he developed blindness of the left eye. The tumour grew slowly during the first years and had among other things caused deformation of the base of the skull (the erosion of the sphenoidal planum and dorsum sellae). The tumour was at least partly covered by a capsule and no evidence of overgrowth either to the bone or to the vessels was found. The vessels resembling moya moya appeared to have developed to compensate for the compression of the anterior cerebral artery so that in spite of a gradually increasing compression the circulation was preserved. The abnormal vessels were obviously collateral vessels and probably of the same type as TAVILLAS (1969) described in his 1968 Caldwell lecture. This author collected 10 cases of intracranial arterial occlusions and at least in 6 cases found large network of fine vessels in the region of the basal ganglia and upper brain stem. He stated that it is also evident that when the disease process starts early in childhood or during infancy the development of the network in the base of the brain is apt to be greater. HANDA & HANDA (1972) also reported that the moya moya like vessels at the base of the brain in all probability might be considered as collateral pathways created by an extraordinary development of perforating vessels to the basal ganglia. These authors were able to demonstrate in

5 of 27 cases that the collateral pathways played a role in the circulation to the peripheral arteries. They also described a case in which the internal cerebral artery was reconstructed by the vascular network in the same way as occurred in the present case with filling of the displaced branches of the right anterior cerebral artery. This fully supports the opinion that, especially among children, long progressive occlusion of the upper part of the internal carotid artery or the proximal parts of the anterior and medial cerebral arteries creates the condition suitable for dilating fine arteries of the basal ganglia. These arteries have the ability of maintaining the circulation to the hemisphere in spite of the proximal occlusion of the original artery. The present case raises no suggestion of primary vascular disease as the whole development was in all probability caused by the slowly growing basal tumour.

SUMMARY

Enlarged arteries of the basal ganglia (moya moya arteries) acting as collaterals have usually been regarded as part of specific Japanese disease. Similar cases with arterial occlusion also from other countries have however been described in recent years in the literature. A case is presented in which such arterial changes were apparently caused by gradual occlusion of the anterior cerebral arteries by a slowly growing tumour.

ZUSAMMENFASSUNG

Eine Erweiterung der Arterien der Basalganglien (moya moya Arterien) die eine Kolateralfunktion haben wurde bisher als typisch für eine spezifisch japanische Erkrankung betrachtet. Ähnliche Fälle alle mit arteriellem Verschluss sind jedoch in den letzten Jahren auch in anderen Ländern in der Literatur beschrieben worden. Ein Fall wird beschrieben in dem die Arterien in kollateralgeklasse wirkten was anscheinend durch einen allmählichen Verschluss der A. cerebri anterior durch einen langsam wachsenden Tumor verursacht war.

RÉSUMÉ

L'augmentation de calibre des artères des noyaux gris centraux (artères moya moya) fonctionnant comme des collatérales habituellement et considérées comme une partie d'une maladie japonaise spécifique. Cependant des cas semblables comportant une occlusion artérielle ont aussi été décrits dans la littérature ces dernières années. L'auteur présente un cas dans lequel des lésions artérielles analogues étaient apparemment causées par une obstruction graduelle des artères cérébrales antérieures par une tumeur. Le développement lent

REFERENCES

- GERLAGH J, JENSEN H P, KOON W und KRALS H: Pädiatrische Neurochirurgie. Georg Thieme Verlag Stuttgart 1967.
 HANDA J and HANDA H: Progressive cerebral arterial occlusive disease. Analysis of 27 cases. Neuroradiology 3 (1972) 119.

- KRAYENBUHL H and YASARGIL M G Die cerebrale Angiographie Georg Thieme Verlag Stuttgart 1966
- LAXER L O and ROSENBERG H Angiographic diagnosis of intracerebral vascular occlusions Acta radiol Diagnosis 2 (1964) 129
- MOUNT L A and TAVERAS J M Arteriographic demonstration of collateral circulation of cerebral hemispheres Arch Neurol Psychiat 78 (1957) 235
- SCHUKI J and TAKEKI A Cerebrovascular moya moyo disease Arch Neurol 20 (1969) 288
- TAKEUCHI K Occlusive disease of the carotid artery Especially on their surgical treatment Shinkai Shumpo 5 (1961) 511
- TAVERAS J M Multiple progressive intracranial arterial occlusions Amer J Roentgenol 106 (1969) 235
- WIDNER W HANAFEE W and MARSHMAN C H Intracranial collateral circulation via leptomeningeal and rete mirabile anastomoses Neurology 15 (1965) 99

ANGIOGRAPHIC ABNORMALITIES IN COMBINED
MYOSITIS OSSIFICANS AND DIGITAL ISCHEMIA
OF THE HAND
Report of a case

ADAM M DUNCAN

Occasionally findings of a bony tumor mass may be associated with arterial and venous occlusions. To differentiate between a vascular dysplasia, malignant tumor or myositis ossificans angiography is a valuable tool (ACKERMAN 1958, HERZBERG & SCHREIFER 1971, LAGERGREN et coll 1960, LEVY et coll 1972, MARSHALL et coll 1966, STENER & WICKBOM 1966). This paper presents a case of myositis ossificans in association with posttraumatic digital ischemia.

Case report

A 36 year old white male cement finisher complained of increasing numbness and stiffness of the fourth and fifth digits of his left hand. Episodes of pain in the left palm brought him to medical attention two years after the onset of symptoms. At that time a detailed history revealed that he rested his left palm on the handle of a trowel while squatting and smoothing

Submitted for publication 19 February 1973



Fig 1 Left hand. A bony mass involving the fourth and fifth metacarpals.

cent with trowel in his right hand. As he moved from one position to the next the left palm acted as a pivot point bearing considerable weight. He worked this way for 10 years and was forced to give up his job after suffering increasing pain and stiffness of the left hand. At that time he first noted a hard mass deep on the palmar surface of his hand. Swelling and paresthesias gradually developed.

Initial films in March 1972 were considered negative. In April early new bone formation adjacent to the fourth and fifth metacarpals was identified. Later in the same month new bone formation appeared extending the length of the shafts of the fourth and fifth metacarpals and filling the space between (Fig 1).

Angiography. Twenty ml Renografin 76[®] was injected manually in the left brachial artery with serial films exposed over the hand using a magnification technique. These films demonstrated narrowing of the ulnar artery with attenuation in the hypothenar space. The arterial phase showed the area of mass to be hypervascular; however, no arteriovenous shunt or aneurysms were seen. There were small occlusions of the 4th and 5th metacarpal arteries in the region of the mass. The superficial and deep palmar arches were incomplete (Fig 2a). In the venous phase there was considerable accumulation of contrast medium and venous occlusions of the proximal portions of the digital veins of the third, fourth and fifth fingers (Fig 2b). Exploration of the palmar space with biopsy and fasciotomy was carried out. The pathologic diagnosis was metaplastic bone consistent with myositis ossificans circumscripta.



b

Fig 2 a) Arteriography arterial phase Incomplete superficial and deep palmar arch and narrowing in the ulnar artery distribution b) Venous phase subtraction Occlusion of the digital ends of the third fourth and fifth digits Accumulation of contrast medium in the region of the myositis ossificans

Discussion

The hypothenar hand syndrome (CALEOFF 1972 COHEN et coll 1970) occurs secondary to repeated blunt trauma (KLEINERT & VOLIANTIS 1963 ZWISLO et coll 1969) to the ulnar artery as it passes adjacent to the hook of the hamate. In such cases the superficial and deep palmar arches are usually incomplete. The ulnar artery which divides into two branches distal to the pisiform bone terminates at the superficial palmar arch. The principle blood supply to the fourth and fifth digit is from the digital arteries of superficial arch origin. In the present case there was occlusion of the superficial and deep palmar arches. This was accompanied by narrowing of the digital arteries to the fourth and fifth fingers. In addition to these findings there was a tumor like accumulation of contrast medium seen in the late arterial and early venous films in the area of the localized

myositis ossificans This finding has been reported by previous authors (HUTCHINSON et coll 1972) in the active stage of this disease. In the venous phase occlusion of the digital veins was identified. This finding has not been previously reported, and appears to represent a mechanical venous obstruction secondary to compression of the digital veins as they pass over the area of localized myositis ossificans and under the palmar aponeurosis. Clinically this resulted in marked swelling of the fourth and fifth fingers.

SUMMARY

Two manifestations of occupational trauma in a 36 year old cement finisher are presented. These include localized myositis ossificans and posttraumatic digital ischemia. Localized hypervascularity and areas of venous obstruction were observed related to the myositis ossificans as well as to arterial narrowing.

ZUSAMMENFASSUNG

Es werden zwei Zeichen eines Berufstraumas bei einem 36 Jahre alten Zementhersteller beschrieben. Diese umfassen eine lokalisierte Myositis ossificans und eine posttraumatische digitale Ischämie. Es wurde eine lokalisierte Hypervaskularität und Gebiete venöser Obstruktion als Folge der Myositis ossificans sowie der arteriellen Einengung beobachtet.

RÉSUMÉ

Présentation de deux manifestations d'un traumatisme professionnel chez un cimentier et toucheur âgé de 36 ans. Elles comprennent une myosite ossifiante localisée et un ischémie digitale post-traumatique. On observe une hypervascularisation localisée et des zones d'obstruction veineuse en rapport avec la myosite ossifiante et avec le rétrécissement artériel.

REFERENCES

- ACKERMAN L. V. Extra-osseous localized non neoplastic bone and cartilage formation (so-called myositis ossificans): clinical and pathological confusion with malignant neoplasms. *J Bone Jt Surg* 40 (1958) 279.
- CALINOV L. Angiography of the hand. Guidelines for interpretation. *Radiology* 102 (1972) 331.
- COTY J. J., BERGAN J. J. and BILL L. J. Hypothenar hammer syndrome: posttraumatic digital ischemia. *Surgery* 68 (1970) 1122.
- HUTCHINSON D. I. and SCHREIBER M. H. Angiography in muscle tears of the extremities. *Amer J Roentgenol* 111 (1971) 341.
- HUTCHINSON J., KLETTE E. C. and KREMER R. The angiographic picture of myositis ossificans circumscripta. *Radiology* 101 (1972) 57.

- KLEINERT H. E. and VOLKOWITZ G. J. Thrombosis of the palmar arterial arch and its tributaries: etiology and new concepts in treatment. *J. Trauma* 5 (1965) 447.
- LACROIX C., LINDHOLM Å. and SÖDERBERG G. Vascularization of fibromatous and fibrosarcomatous tumors. Histopathologic, microangiographic and angiographic studies. *Acta radiol.* 55 (1960) 1.
- LEVIN D. C., WATSON R. C. and BALTAXI H. A. Arteriography in diagnosis of acquired peripheral soft tissue masses. *Radiology* 103 (1972) 55.
- MARSHALL T. R., NEUSTADT H., CHUMLEY W. I. and KAMMAN M. L. Hand arteriography. *Radiology* 86 (1966) 299.
- STEINER D. and WICKHAM I. Angiography in three cases of muscle rupture with organizing haematoma. *Acta radiol. Diagnosis* 4 (1966) 169.
- ZWING J., LEE H. K., POSCH J. L. and LARSEN R. D. Thrombosis of the ulnar artery following blunt trauma to the hand. *J. Bone Jt. Surg.* 51A (1969) 1191.

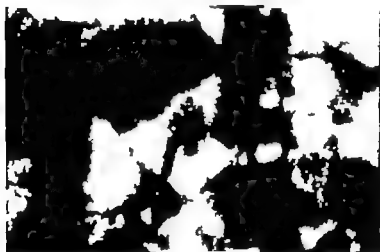
PHARMACOANGIOGRAPHY OF THE LEFT GASTRIC ARTERY IN OESOPHAGEAL VARICES

ANDERS LUNDBERGST

Röntgenologic examination of hepatic cirrhosis usually comprises (1) barium examination of the oesophagus to demonstrate oesophageal varices, (2) angiography of the coeliac artery to define the liver splenic and portal veins and venous collaterals, (3) pharmacangiography of the superior mesenteric artery with bradylinin or priscoline to demonstrate the portal vein and venous collaterals, (4) wedge pressure recording in one hepatic vein combined with phlebography with the catheter in the wedge position.

Pharmacangiography of the left gastric artery with bradylinin has also been added to the examination for portal hypertension when the venous collateral circulation in the wall of the fornix of the stomach and lower oesophagus cannot otherwise be demonstrated.

Method Selective catheterization of the left gastric artery is performed with a catheter (OD 2.2 mm ID 1.4 mm). Ten μ g bradylinin are injected into the artery followed in 20 to 30 seconds by 30 ml of contrast medium (Iopaque Coronar 370 mg I/ml) at a rate of about 5 ml/s. Exposures are then made 1/s at two seconds, 2/s at five seconds and one every other second for 8 seconds. The vascular dilatation and increased blood flow produced by bradylinin will give high concentration of the contrast medium in the veins draining the stomach and make them easier to observe.



b

Fig. 1 Sixty-three-year-old woman with hepatic cirrhosis and oesophageal varices suggested by barium examination. a) Coeliac angiography: early phase. Filling of splenic and portal veins; upper part of inferior mesenteric vein (\rightarrow) and an omental vein from the hilum of the spleen. Short gastric veins and coronary vein remain unfilled. b) Pharmacovascular angiography with bradykinin of superior mesenteric artery: early phase. Linear inflow of blood from splenic vein into portal vein. No collaterals filled.



Fig 2 Same case Pharmacoaangiography with bradykinin of left gastric artery enosis phase Dilated tortuous cerna in the form of the stomach and lower oesophagus are filled

Discussion

Laenoportal phlebography has been almost abandoned in the roentgen examination of hepatic cirrhosis and portal hypertension during the last few years. Selective injection of a large amount of contrast medium into the coeliac or splenic arteries and pharmacoaangiography of the superior mesenteric artery with bradykinin or tolazoline will usually render evaluation of the splenic and portal veins and their collaterals possible.

Laenoportal phlebography with a rather high frequency of complications may be left to the few occasions where the arteriographic examination cannot produce all the information necessary for operation. Investigations have indicated that intrasplenic arterial aneurysms are overrepresented in patients subjected to percutaneous splenic portotomy. This further stresses the value of arterial portography. Moreover even in laenoportal phlebography unfavourable flow and layering of the contrast medium may mask collaterals.

Where oesophageal anastomosis has sometimes been suggested at barium examination in hepatic cirrhosis and portal hypertension it has been impossible to demonstrate these with arteriography (Fig 1). Selective pharmacoaangiography of the left gastric artery with bradykinin produced filling of

dilated tortuous veins with contrast medium of high concentration and excellent demonstration of oesophageal varices (Fig 2). The reason for non filling of the oesophageal varices at angiography of the coeliac and superior mesenteric arteries must be layering of the medium to more dorsal parts of the splenic and portal veins. When the venous collaterals arise from the ventral part of these main stems blood without contrast medium will pass through the venous collaterals towards the oesophagus the oesophageal varices probably cannot then be demonstrated even by hepatoportal phlebography.

The high concentration of the contrast medium in the collateral veins from the stomach during pharmacangiography of the left gastric artery with bradylinin will presumably make this method useful even to demonstrate bleeding from oesophageal varices through extravasation of the medium.

SUMMARY

Pharmacangiography of the left gastric artery with bradylinin has been used to demonstrate oesophageal varices. The method which is described and discussed may further reduce the need for hepatoportal phlebography in portal hypertension.

ZUSAMMENFASSUNG

Die Pharmakoangiographie der linken Magenarterie mit Bradylinin wurde verwendet um Oesophagusvarizen nachzuweisen. Die Methode, die beschrieben und diskutiert wird, mag die Notwendigkeit einer hepatoportal Phlebographie bei einer portalen Hypertension weiter verringern.

RÉSUMÉ

L'angiographie de l'artere gastrique gauche dont le comportement avant et modifié par la bradylinine a servi à mettre en évidence des varices œsophagiennes. Cette méthode qui est décrite et étudiée peut réduire encore les indications de la phlébographie splénoportale dans l'hypertension portale.

REFERENCES

- BERGSTRAND I and ELMAN C A Percutaneous hepato-portal venography. *Acta radiol* 47 (1957) 269
- BOJSEN E and REDMAN H C Effect of bradylinin on coeliac and superior mesenteric angiography. *Invest Radiol* 1 (1966) 422
- and ERINO H O I transplenic arterial aneurysms following splenoportal phlebography. *Acta radiol. Diagnosis* 6 (1967) 487
- REDMAN H C RAEGER S R and MILLER W J Improvement of superior mesenteric and portal visualization with tolazoline. *Invest Radiol* 4 (1969) 24
- REUTER S R and STARY T W High dose left gastric angiography for demonstration of oesophageal anries. *Radiology* 103 (1972) 573
- SCHÖDIN R Selective angiography of the left gastric artery. *Acta radiol* (1970) Suppl. 299

FUNCTIONAL ISOTOPE PHLEBOGRAPHY OF LOWER EXTREMITIES

J VITEL, A HUVAR and F VRUBEL

Isotope arteriography in which a small amount of isotope was injected intra-arterially in obliterative diseases of the lower extremities has previously been described (VITEL et coll 1967). Since then a similar isotopic method has been employed in the investigation of the normal system as well as the occluded or otherwise diseased venous system of the lower extremity.

This distinction proved impossible to assess from the speed of the venous flow in a patient standing for although marked individual differences were apparent. The difference in the average circulation time of the individual groups of assessment was negligible. The conclusion was thus reached that only curves representing the dynamic function of the venous system with various diseases will prove of real value. The method is suited for functional isotope phlebography.

Methods. A vein of the dorsum of the unloaded foot with the patient standing is injected with 10 ml of isotonic saline containing 25 μ Ci of 125 I labelled

Submitted for publication February 5

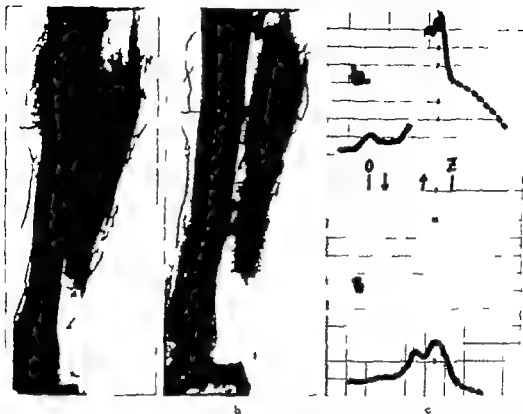


Fig. 1 Functional phlebography a) after the injection of contrast medium and b) during the muscular contraction when the medium is being emptied. Isotope phlebogram. Activity rises rapidly when the extremity is being loaded, sharp fall in activity during contraction of muscle pump when isotope is washed out. (In all curves shank probe is marked b and thigh probe c. Curve read from right to left. Phases of exercise: 0—the extremity loaded, ↓—weight on toes, ↑—stepping back on sole, 0—extremity unloaded.)

serum albumin. The patient then simulates walking by repeatedly transferring his weight to the extremity under examination and stepping lightly on the tip of the toes, back onto the sole, and then transferring the weight to the sound leg. Curves were obtained by two probes of a Duovigraph AGECE with the shank probe at the lower margin of the triceps and the thigh probe above the upper margin of the patella. Patients had rehearsed the procedure and were instructed not to move away from the probes. Values used: sensitivity $3 \cdot 10^4$ or 10^5 , time constant 0.03/s, speed of paper feed 1 cm/s. Thirty patients mostly with varicocules were examined.

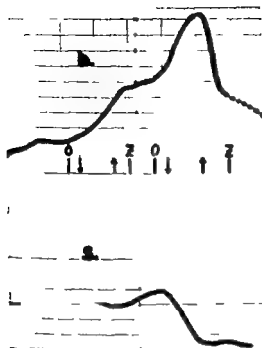


Fig 1 Isotope phlebogram of normal venous system

Results

Fig 1 a and b depict functional phlebography in a normal venous system. A single muscle contraction nearly empties the whole system. Fig 1 c is of the corresponding isotope curve. The shank probe is marked b and the thigh probe a. The curves should be read from right to left. Each phase of the walk is marked: Z = extremity loaded, ↑ = pressure on toes, ↓ = back onto sole, 0 = extremity unloaded. Loading of the extremity produces a rapid rise of activity in the shank probe while the pump contraction of the muscle causes a rapid fall following the wash out of the isotope. The thigh probe indicates constant conditions. The system is emptied within one exercise.

The curve of a normal venous system with the same phases (loading and muscular contraction) are presented in Fig 2. Emptying takes place after two steps. Similar curves representing good function are always obtained when the varicosities are not too large and with a normal deep system. Two phases of functional phlebography appear in Fig 3: (a) filling in the unloaded extremity, (b) muscular contraction (constant medium forward in the deep system).



Fig 5 Functional phlebogram a) Filling in an unloaded extremity b) muscular contract as movement of contrast medium in deep system with disappearance of filling of muscle vein c) Extremity unloaded with corresponding disappearance of medium and refilling of muscle veins

centrally and filling of muscle veins disappearing) (c) unloading with disappearance of the medium and a further filling of the muscle veins. The corresponding isotope curve is almost that of a normal function curve (Fig 4). It differs only in a slight fresh rise in activity after the extremity has been loaded i.e. in the flow of activity from the peripheral reservoir. The shank system is emptied after three steps.

Fig 5 a is of an entirely different curve. Irregular oscillation of activity with slow emptying without typical phases of a normal function is evident. The deep system is entirely occluded in the contrast phlebogram (Fig 5 b c) the patient suffered from acute phlebothrombosis with swelling of the whole extremity.

In the following patient the curve is atypical with minimal emptying appearances (Fig 6 a). A more substantial decline took place only after 50 s of

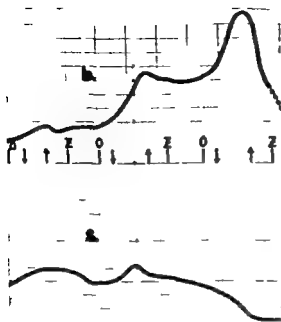


Fig 4 Same case Isotope phlebogram. The curve resembles that of normal venous system but the reflux of activity from peripheral reservoir causes a slight rise in activity after the extremity has been loaded.

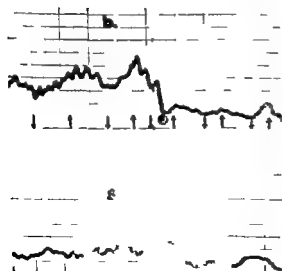


Fig 5) Iso phases of normal and) lateral p

normal venous system (left) and lateral p (right)

activity oscillates on with slow emptying without typical rise in sensitivity of probes) Phlebograms in b) p union of deep system





Fig 6a



Fig 6b

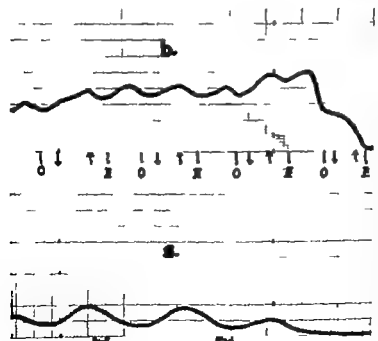


Fig 7

Fig 6 a) Isotope phlebography. Atypical curve with minimal emptying. Patency of the deep system and normal mechanism of muscle pump absent. b) Large haemangioma in calf muscles.

Fig 7 Isotope phlebography. Characteristic double hump caused by further rise in activity following each loading, but even loading of extremity the suction phase slow total decline of activity.



Fig 8 Same case Functional phlebography a) Filling in the unloaded leg b) muscular contraction c) Repeated unloading with minimal disappearance of the contrast medium d) after five steps Considerable residue of contrast medium

exercise. This points again to an occlusion of the deep system and absence of the normal mechanism of a muscle pump, in this instance as a result of a large haemangiomatous cavernous malformation in the calf muscles with an atypical draining vein (Fig 6 b).

Fig 7 depicts the third type of curve. Its characteristic is a double hump brought about by a further rise in activity after each loading as well as unloading of the leg i.e. in the action phase. The general decline in activity is slow, each muscular contraction being accompanied by a decline. The venous system as a whole is insufficient, though the deep system is patent. Corresponding phlebograms appear in Fig 8. a) filling of an unloaded extremity (b) contraction (c) fresh unloading with a minimal disappearance of contrast medium (d) after five steps with a small residual contrast residue.

Functional isotope phlebography is a reliable means of depicting the function of the venous system of the lower extremity and can distinguish between its normal function and insufficiency. This can be effected with greater sensitivity than contrast phlebography in which the appearances are disfigured by specifically heavy contrast media. However it cannot distinguish between the causes of insufficiency, i.e. whether the latter is produced only by varicosities and insufficient perforators or by the insufficiency of the deep venous system. Functional isotope phlebography may demonstrate occlusion of the deep venous system but not its cause.

SUMMARY

Functional isotope phlebography is a method of assessing normal or insufficient function of the venous system of the leg. The procedure was applied in 30 patients predominantly suffering from varicosities. Three types of functional curves have been assessed: these correspond to normal and insufficient function of the venous system as a whole and will reveal occlusion when present.

ZUSAMMENFASSUNG

Die funktionelle Isotopenphlebographie ist eine Methode um eine normal oder insuffiziente Funktion des Venensystems des Beines abzuschätzen. Das Verfahren wurde bei 30 Patienten, die hauptsächlich an Krampfadererkrankungen litten, verwendet. Drei Typen von funktionellen Kurven wurden festgestellt: diese entsprechen einer normalen oder insuffizienten Funktion des Venensystems als Ganzes und lässt eine eventuell vorhandene Okklusion erkennen.

RÉSUMÉ

La phlebographie isotopique fonctionnelle est une méthode pour déterminer la fonction normale ou insuffisante du système veineux du membre inférieur. Cette technique est appliquée chez 30 malades souffrant principalement d'artérites. Les auteurs ont trouvé 3 types de courbes fonctionnelles: elles correspondent à une fonction normale et insuffisante du système veineux dans son ensemble et montreraient une occlusion si elle existait.

REFERENCES

- CUTPERS Y. Etude de la circulation sanguine périphérique à l'aide de l'albumine humaine marquée ^{131}I . *Acta cardiol.* 19 (1964) 248.
 VÍTEK J., ZAVÁŘIL I., HUVAR A. a KASPAR Z. Isotopová arteriografie u obliteračních chorob tepen dolních končetin (In Czech). *Čas. lēk. ces.* 110 (1971) 329.
 — — — — and KOVÁČEK V. Isotope arteriography in obliterative arterial disease of the lower extremities. *Acta radiol. Diagnosis* 8 (1967) 463.
 WAGNER P. G. Kreislaufdiagnostik mit Hilfe radioaktiver Isotopen. I. Künstliche radioaktive Isotope in Physiologie, Diagnostik und Therapie. 2. Aufl. 2. Band. II S. 524. Springer Verlag, Stuttgart 1961.

SCINTIGRAPHY OF THE PARASTERNAL LYMPHATICS IN THE RABBIT USING TECHNETIUM 99m SULFIDE COLLOID

L. R. GORANSON and K. JONSSON

The parasternal lymph nodes form one of the main drainage areas of the breast. TURNER WAPWICK (1958) has shown that 75 per cent of the lymph flow from the breast goes to the axillary lymph nodes, while the remaining 25 per cent goes to the parasternal lymphatics. The clinical importance of this fact has been documented¹ by ANDREASSOV et coll (1954) who found that 1/3 of the medially located breast carcinomas and 1/10 of those laterally located had parasternal lymph node metastases.

It is important to know the spread of a malignant tumour preoperatively in order to simplify the operation and the irradiation techniques. The axillary lymph nodes can be examined by direct arm lymphography. For the parasternal lymph nodes, indirect lymphographic technique is available but radioactive tracer

techniques have been described (ROSSI & FERRI 1966 DIETHELM *et coll* 1967 SCHENA 1966). These authors used ^{197}Au colloid injected subcutaneously on both sides of the xiphoid process or in the midline behind the process. The locally absorbed radiation dose is however very high when ^{197}Au -colloid is deposited locally (HAUSER *et coll* 1969 HERTINO *et coll* 1970) and radiation necrosis at the site of injection has been reported (HAAS *et coll* 1970).

Lymph scintigraphy of the retroperitoneal lymph nodes has been successfully performed using $^{99}\text{Tc}^m$ S colloid (HAUSER *et coll* 1969 FAIRBANKS *et coll* 1972). The locally absorbed radiation dose is much lower as compared to ^{197}Au colloid and there is no risk of local radiation necrosis.

The purpose of this investigation was to ascertain whether $^{99}\text{Tc}^m$ S colloid injected subcutaneously can be used for scintigraphy of the parasternal lymphatics, and if the resorption of the colloid depends on or is enhanced by hyaluronidase.

Material and Methods The rabbits used for the experiments weighed between 1.5 and 3.0 kg. They were anaesthetized with intravenous Pentobarbitone sodium (Mebumalnatrum ACO Sweden) and the upper part of the abdomen around the xiphoid process was shaved with an electric razor.

The $^{99}\text{Tc}^m$ S-colloid was prepared according to PERSSON & NAVERSTEN (1970). The mean size of the colloid particles was estimated to be $0.7 \pm 0.3 \mu\text{m}$. The physical half life of $^{99}\text{Tc}^m$ is six hours, and the measurements are performed with pulse height analyses in the energy interval 119/161 keV. After injection of the colloid the animals were placed in supine position under a 4 000 channel or a pinhole collimator of a gamma camera (Nuclear Chicago Pho Gamma III).

In group I consisting of 10 animals 250 μCi of $^{99}\text{Tc}^m$ S colloid were injected subcutaneously on each side of the xiphoid process. The volume of each injection was 1 ml. No local anaesthesia was given before the injection. In group II consisting of 11 animals the same amount of colloid and the same technique were used as in the first group except that 100 IU hyaluronidase (Hyalas Leo Sweden) was injected subcutaneously two minutes before the injection of the colloid. The volume of hyaluronidase for each injection was 1 ml. The third group consisted of 11 animals and they were injected on both sides of the xiphoid process with 250 μCi $^{99}\text{Tc}^m$ S-colloid concentrated to a volume of 1/2 ml, and 100 IU hyaluronidase was dissolved in the concentrated colloid.

The uptake of colloid in the lymph nodes was recorded for periods of 15 to 120 minutes by the Inter technique system of cine scintigraphy used with the Nuclear Chicago Pho Gamma III.



Fig 1 Distribution of radioactive colloid in a rabbit from Group III 2 to 15 minutes after injection. The site of injection is seen in the upper part of the abdomen. Lymph nodes evident in the upper mediastinum on both sides of the midline.

Results

No lymph nodes in the intercostal spaces were detected in any of the animals.

Two groups of lymph nodes are located in the upper mediastinum: one on the right side and one on the left side, filled from parasternal lymphatics on the respective sides. The presence of normal parasternal lymph flow was assumed when these lymph nodes were filled with the isotope.

In group I, where only $^{99}\text{Tc}^m\text{S}$ colloid had been injected, uptake in the upper mediastinal lymph nodes occurred in only four animals: on both sides of the midline in one and on only one side in the remaining three. The uptake was faint and could first be detected after one hour.

In group II, where the injection of radioactive colloid was preceded by hyaluronidase, bilateral filling of the upper mediastinal lymph nodes occurred in six animals within 2 to 25 minutes. In four animals no lymph nodes were detected, and in one animal the colloid at the site of injection had spread out on the chest wall and no lymph nodes could be identified.

In group III, where the animals were injected with concentrated colloid mixed with hyaluronidase, the upper mediastinal lymph nodes were observed bilaterally in six animals within 2 to 12 minutes (Fig 1). The colloid uptake in three animals was recorded for 120 minutes. In this group the resorption and

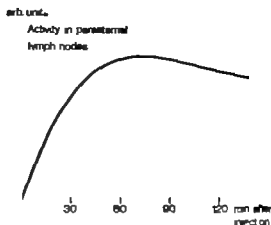


Fig. 2 Activity curve in a parasternal lymph node of the upper mediastinum

filling of the mediastinal lymph nodes started almost immediately after injection. The activity in the lymph nodes increased linearly for 60 to 80 minutes then reached a plateau or decreased slightly (Fig. 2).

Discussion

The lymph flow from the breast and the lymphatic spread of carcinoma of the breast has been given much attention in the literature. HULTBORN *et coll* (1955) showed with an isotope technique that the lymph flow from all parts of the breast goes to both the axillary and the parasternal lymph nodes. TURNER WARWICK (1958) concluded that 75 per cent of the lymph flow from the breast goes to the axillary nodes and 25 per cent to the parasternal nodes. The clinical importance of this fact in patients with carcinoma of the breast has been demonstrated by ANDRUSSEV *et coll* (1954) and URBAN & MARJANI (1971). The latter authors found parasternal lymph node metastases in 53 per cent of 725 extended radical mastectomies. The possibility of preoperatively diagnosing parasternal lymph node metastases has so far been rather limited. A method for the biopsy of these nodes (HANDLEY & THACKRAY 1949, 1954) appears to have only limited practical use, although the results reported are excellent. KETT *et coll* (1970) have described a method of direct lymphography of lymph vessels of the breast. The technique is difficult, and seems to have limited value for the parasternal lymphatics.

MASSOUD *et coll* (1964) have reported a series of 66 patients where they performed tomography of the anterior mediastinum, in most cases in combination with induced pneumomediastinum. The smallest lymph node metastases found had a diameter of 0.6 cm.

Transsternal phlebography for detection of parasternal lymph node metastases can be employed but the results obtained are only reliable for the first and second intercostal space (CHERNOMORDIAOVA et coll 1972). The most common diagnostic method for detecting parasternal lymph node metastases seems to be lymph node scintigraphy first described independently in 1966 by DIETHELM et coll. Rossi & FENZI and SCHENA. Their technique, in some cases with slight modifications has later been used by other authors. SCHENA et coll (1966) Rossi et coll (1968) MICHAILOV et coll (1968) KAZEM et coll (1968, 1969) SEIFERT & BETZNER (1970) and MEYER BURD & WILHELM (1971).

GROS et coll (1972) injected the ^{198}Au -colloid on the dorsum of both hands, in the axillary line of the 7th intercostal space and in the midline behind the xiphoid process for a total evaluation of the lymph drainage of both breasts. Lymph node scintigrams have been performed 24 to 48 hours after injection of the colloid in all these investigations. In case of metastases, the parasternal lymph nodes do not fill with the colloid. Due to poor resolution, no details of the individual lymph nodes can be detected. Wide normal variations in the anatomy of the lymph nodes in the parasternal region (STIBBE 1918) also make the interpretation difficult.

Although ^{99}Tc S colloid has been used for scintigraphy of the retroperitoneal lymph nodes (HAUSER et coll 1969 FAIRBANKS et coll 1972) it has not been used for scintigraphy of the parasternal lymph nodes with subcutaneous injection of the colloid. ATAMS et coll (1970) reported one case of filling of the diaphragmatic lymph nodes in man following intraperitoneal injection of ^{99}Tc S colloid. It has also been used experimentally for examination of the parasternal lymphatics after intraperitoneal injection (GORANSON et coll 1973). The colloid is resorbed through lymph vessels in the diaphragm to the parasternal lymphatics. However this transabdominal injection technique requires fluoroscopy in order to control the position of the needle and to ensure that the injection is made in the free peritoneal cavity. A subcutaneous injection of the colloid undoubtedly is much simpler for the patient than the technique with intubation of the technetium colloid on both sides of the xiphoid process was tried.

As expected the resorption of the colloid was enhanced by hyaluronidase (first used in clinical practice by OLSSON & LOREN in 1949). This has been pointed out in all previous reports on lymph node scintigraphy with the exception of KAZEM et coll (1969). The colloid was resorbed very slowly when hyaluronidase was not used, resulting in only faint uptake of the isotope in the upper mediastinal lymph nodes in a few animals.

The best way to use the hyaluronidase was to dissolve it in the colloid before injection in the cutis. Hyaluronidase is highly soluble in the colloid and the volume injected can be kept to a minimum. This procedure also ensures that the

hyaluronidase and the colloid are injected at exactly the same spot. When the hyaluronidase is injected before the technetium colloid, the two solutions may be injected at different levels of the cutis, and no enhancement of the resorption will occur. Another disadvantage is that the volume injected will be greater as the hyaluronidase must be separately dissolved in saline. A third disadvantage with a greater injection volume is that the radioactive substance easily flows out and after a short while is spread out over a large area of the upper abdomen and the chest wall, thereby covering the lymph nodes.

No intercostal lymph nodes could be identified in the rabbits, in contrast to the published reports of parasternal lymph scintigraphy in man. This was also found in a previous report (Goranson et coll. 1973). It is not certain whether this is due to the minute size of the lymph nodes in the rabbit or if these lymph nodes are absent in the rabbit.

When the colloid and hyaluronidase are mixed together the uptake in the lymph nodes shows an almost immediate and linear increase. Maximum is reached after 60 to 80 minutes followed by a steady state or by a slight decrease depending on the biologic and physical decay of the technetium colloid. To obtain maximum information it is necessary to follow the uptake for about 1 1/2 hours, although the question of filling versus non filling is answered within half an hour or less.

The method is planned to be used in man and if the experimental data are applicable, the results of the examination are obtained much sooner with ^{99}Tc S colloid than with ^{125}I An colloid.

Acknowledgement

This investigation was supported by grants from the Swedish Medical Research Council Project no. B73 142 605 07B, the John and Augusta Persson's Foundation for Medical Research and the Faculty of Medicine, Lund University.

SUMMARY

Parasternal scintigraphy with ^{99}Tc S colloid has been performed in rabbits. The colloid was injected on both sides of the xiphoid process. Hyaluronidase dissolved in the colloid was the most favourable method for enhancing the resorption.

ZUSAMMENFASSUNG

Es wurde eine parasternale Skintigraphie mit ^{99}Tc S Kolloid bei Kaninchen vorgenommen. Das Kolloid wurde zu beiden Seiten des Processus xiphodeus injiziert. Hyaluronidase gelöst im Kolloid war die vorteilhafteste Method um die Resorption zu erhöhen.

RÉSUMÉ

Les auteurs ont fait sur des lapins des scintigraphies parasternales avec un colloïde ^{99}Tc -S. Ce colloïde a été injecté des deux côtés de l'appendice xiphoïde. L'hyaluronidase dissout dans le colloïde est le moyen le plus favorable pour faciliter la resorption.

REFERENCES

- ANTONIAK M, DART IVERSEN E and SCHREIBER B. Glandular metastases in carcinoma of the breast. *Lancet* 266 (1954) 176
- ATKINS H L, HAUSER W and RICHARDS P. Visualization of mediastinal lymph nodes after intraperitoneal administration of ^{99}Tc Sulfur colloid. *Nucl Med (Stutg)* 9 (1970) 275
- CHERNOMORDIKOVA M F, DEDMARSKY L Y, KHOLDEY S A and SELIKOV I K. Limits and possibilities of transternal phlebography for detection of metastases in the internal mammary lymph nodes. *Radiology* 102 (1972) 291
- DIEZHELM L, BUCHWALD W, HAAS J P and WOLF R. Erweiterung der Diagnostik des Mammakarzinoms mit Hilfe von Isotopen. *J Radiol Electrol* 48 (1967) 677
- FAIRBANKS V F, TAUBER W N, BIRLEY J M and MILLER W E. Scintigraphic visualization of abdominal lymph nodes with ^{99}Tc Pertechnetate labeled sulfur colloid. *J nucl Med* 13 (1972) 185
- GROS CH, VERLORES R, BECKHOFMAN P et TRUCROT M. Place actuel de la lymphographie isotopique dans l'exploration du cancer du sein. *J belge Radiol* 55 (1972) 59
- GORANSON L R, JOHANSON K and OLIN T. Transabdominal roentgenologic and scintigraphic lymphography of the ventral mediastinum with thorotrast and ^{99}Tc -S-colloid in the rabbit. *Acta radiol Diagnosc* 14 (1973) 757
- HAAS J P, BUCHWALD W and WOLF R. Zur Frage der Strahlenbelastung der Injektionsstelle bei der Lymphknotenscintigraphie mit kolloidaalem ^{99}Tc -S. Radioaktiv. Isotope in Klinik und Forschung. Vol 9 (1970) 40. Urban und Schwarzenberg München Berlin Wien
- HANDLEY R S and TRACERAY A C. The internal mammary lymph chain in carcinoma of the breast. Study of 50 cases. *Lancet* 2 (1949) 276
- — Invasion of internal mammary lymph nodes in carcinoma of the breast. *Brit med J* 1 (1954) 61
- HAUSER W, ATKINS H L, RICHARDS P. Lymph node scanning with ^{99}Tc Sulfur colloid. *Radiology* 92 (1969) 1359
- HEKTING S E, BUCHLER FREDRIKSEN P, JAST T and JEFFERSON P. Lymph node scanning with colloidal radioactive gold. *Acta radiol Diagnosc* 10 (1970) 359
- HULTGREN K A, LARSSON L G and RAGNVALT I. The lymph drainage from the breast to the axillary and parasternal lymph nodes studied with the aid of colloidal Au 198 . *Acta radiol* 43 (1953) 32
- KAZEM I, ANTONIAK J, BRADY L W, FAUST D S, CROLL M N and LIGHTFOOT D. Clinical evaluation of lymph node scanning utilizing colloidal gold 198. *Radiology* 90 (1968) 905
- BRADY L W, CROLL M N, FAUST D S and WOLFFERTH C C. The parasternal lymph node scan as prognostic test in breast carcinoma. *Radiology* 92 (1969) 617
- KETT K, VARGA G and LUKACS L. Direct lymphography of the breast. *Lymphology* 1 (1970) 3

- MARROUD G. E., AWMAD H. K. and EL KHARADLY M. E. A. The radiological investigation of internal mammary lymph node metastases in breast cancer. *Clin Radiol* 54 (1964) 179.
- MEYER BURK J. und WILHELM U. Ergebnisse skintigraphischer Untersuchungen parasternaler Lymphknoten mit Au^{198} bei Normalpersonen. *Fortschr Röntgenstr* 115 (1971) 54.
- MICHAÏLOV V., MITROV G. und MLATSIKOV G. Indirekt Isotopenlymphographie der parasternalen Lymphknoten mit radioaktivem Gold Au^{198} . *Rad. Biol. Ther.* 9 (1968) 299.
- OLSSON O. and LOFVIG O. Hyaluronidase as a factor hastening the spread and absorption of water soluble radiopaque substances deposited intracutaneously, subcutaneously or intramuscularly. *Acta radiol* 31 (1949) 250.
- PERSSON B. and NAVERTEN V. Technetium 99 m sulfide colloid preparation for scintigraphy of the reticuloendothelial system. *Acta radiol Ther. Phys. Biol* 9 (1970) 567.
- ROSSI R. e FERRI O. La visualizzazione della catena mammaria interna con Au^{198} . (In Italian) *Minerva med* 57 (1966) 1151.
- — — TRIVELLINI G. La linfoscintigrafia mammaria interna con Au^{198} . Ricerca sperimentale ed impiego clinico. (In Italian) *Arch. ital. Chir.* 94 (1968) 33.
- SCHWAL P. Skintigraphische Darstellung des parasternalen Lymphsystems. *Strahlentherapie* 130 (1966) 504.
- zum WINKEL K. und BECKER J. Die Skintigraphie des parasternalen Lymphsystems. *Nucl. Med. (Stuttg.)* 5 (1966) 388.
- SEIFERT J. und BEYERER J. Die indirekt parasternale Lymphskintigraphie beim Mamma-Larzinom. *Fortschr. Röntgenstr.* 113 (1970) 457.
- STEWART P. The internal mammary lymphatic glands. *J. Anat.* 52 (1918) 257.
- TURKEL WARREN R. T. The lymphatics of the breast. *Brit. J. Surg.* 46 (1958) 574.
- URBAN J. A. and MARJANI M. Significance of internal mammary lymph node metastases in breast cancer. *Amer. J. Roentgenol* 111 (1971) 130.

GRADING OF OSTEOPOROSIS BY SKELETAL ROENTGENOLOGY AND BONE SCANNING

N DALÉN and B LAMKE

Osteoporosis may be graded according to various criteria. Skeletal roentgenology makes it possible to determine a large number of morphologic parameters of osteoporosis while bone scanning enables the amount of bone mineral to be measured in different parts of the skeleton. Since however changes in the skeletal morphology and mineral content are not identical criteria of osteoporosis, the results of an investigation may depend upon the method used as well as upon the part of the skeleton examined. The degree of osteoporosis is unlikely to be uniform throughout the skeleton.

The purpose of the present investigation was to compare these two methods in randomly selected subjects, and to examine the relationship between the mineral content and the morphology in different parts of the skeleton.

Methods and Material The roentgenologic classification was made in accordance with two principles, namely by examination of the trabecular structure and measurement of the cortical thickness of long bones. The trabecular structure of the lumbar spine was graded in a lateral film as described by SAVILL (1967).

Submitted for publication: April 1973

Table 1

Precision (1 SD) of the roentgenologic classification including re-film, and intra-observer errors as obtained from replicate measurements in 16 patients expressed as a percentage of the mean of the values observed at the respective sites

Site	Precision
Tibular score Lumbar spine	24.0
Femur neck	15.0
Outer diameter Metacarpal bone II	1.9
Radius	3.1
Femur	1.5
Inner diameter Metacarpal bone II	2
Radius	8
Femur	6.1

and of the femoral neck in an a.p. projection by the method of SNOU ET AL. (1970). The inner and outer diameters of the cortex at the middle of the second metacarpal bone (BARNETT & NORDIN 1960) of the proximal part of the radius (MEEMA 1963) and of the shaft of the femur (BARNETT & NORDIN 1960) were measured. Cortical areas and cortical ratios were calculated by the following formulas: cortical ratio = $(D - d)/D$ and cortical area = $D^2 - d^2$. D = outer diameter and d = inner diameter.

Table 2

Precision (1 SD) of bone scanning as obtained from replicate measurements in 26 subjects expressed as percentage of the mean bone mineral content at the respective sites

Site	Precision
Metacarpal bone II midshaft	1.5
Radius + ulna distal	5.5
Radius + ulna shaft	0.9
Humerus head	2.2
Third lumbar vertebra	10.0
Femur neck	1.9
Femur shaft	2.4
Calcaneus	3.4

Table 3

Morphologic parameters and their standard deviation (SD) for different parts of the skeleton for different age and sex groups expressed as percentages of the mean for the youngest female group. The cortical diameters are corrected for body size.

	Females						Males			
	30-39		40-49		50-59		40-49		50-59	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Lumbar spine trabecular score	100	7	91	20	61	31	94	15	80	31
Femur neck trabecular score	100	12	82	19	66	21	8	24	78	21
Metacarpal bone cortical ratio	100	15	87	14	79	16	84	18	81	13
Radius proximal cortical thickness	100	15	98	16	79	23	95	14	92	16
Outer diameter metacarpal bone	100	7	103	8	105	8	104	9	102	10
prox radius	100	10	109	7	101	8	108	9	111	7
femoral shaft	100	7	106	7	108	8	119	18	124	11
Inner diam ter metacarpal bone	100	32	124	23	14	20	135	27	133	1
prox radius	100	16	112	12	119	19	119	16	124	11
femoral shaft	100	16	110	16	108	10	112	17	118	13

Table 4

Bone mineral content corrected for body size and standard deviation (SD) for different parts of the skeleton for different age and sex groups expressed as percent of the mean for the youngest female group.

	Females						Males			
	30-39		40-49		50-59		40-49		50-59	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Metacarpal bone II	100	11	99	9	86	13	108	10	110	12
Radius+ulna distal	100	20	93	20	74	26	112	10	110	20
Radius+ulna shaft	100	10	100	9	86	17	118	9	118	11
Humerus head	100	21	90	23	58	41	113	13	114	19
Third lumbar vertebra	100	15	86	18	61	20	96	15	86	16
Femur neck	100	14	96	15	89	17	109	14	103	11
Femur neck medial part	100	15	101	15	96	15	92	18	89	1
Femur neck central part	100	18	85	19	75	25	83	15	74	16
Femur shaft	100	8	103	12	85	11	108	7	104	15
Calcaneus	100	12	100	15	85	14	105	14	106	11

Table 5

Spearman Rank Correlation coefficients between morphologic parameters. All coefficients between -0.25 and 0.25 are omitted. The values were corrected for age, sex and body size before the coefficients were calculated.

	Trabecular score		Cortical ratio			
	Lumbar spine	Femoral neck	VI	II	Rad	Fem
Lumbar spine	1.0	0.35	—	—	—	—
Femoral neck	0.35	1.0	—	—	—	—
Cortical ratio						
Mc II	—	—	1.0	—	0.34	0.34
Radius	—	—	—	0.34	1.0	0.28
Femur	—	—	—	0.34	0.28	1.0
Cortical thickness						
radius	—	0.28	0.57	—	—	0.33
Inner diam.						
Mc II	—	—	-0.35	—	-0.36	-0.35
Radius	—	—	-0.50	—	-0.55	-0.53
Femur	—	—	-0.29	—	-0.29	-0.66
Cortical area						
Mc II	—	—	—	—	—	—
Radius	—	0.30	—	—	-0.50	—
Femur	—	—	—	—	—	0.46

The grading of osteoporosis in trabecular bones was based on the following criteria:

Lumbar spine — Group 5 Normal bone structure Group 4 End plates begin to stand out Group 3 Vertical striation more obvious Group 2 End plates less visible Group 1 No trabeculae visible

Femoral neck — Group 6 Normal bone structure Group 5 Slight reduction of trabeculae in the central part Group 4 Lateral trabeculae reduced in number the reduction proceeding outward from the center Group 3 Further reduction of lateral trabeculae Group 2 Only medial trabeculae stand out prominently Group 1 Even the medial trabeculae are markedly reduced in number

The precision of the roentgenologic appraisal was determined by replicate determinations in 16 patients at intervals of at least a week. All the films were exposed by the same radiographer in the same roentgen unit and were examined by the same radiologist. The precision, which included intra-observer and re-filming errors, is indicated in Table 1. The results are consistent with those previously reported (MAZESS et coll. 1968).

The bone mineral content was determined by roentgen spectrophotometry (JACOBSON 1964; GUSTAFSSON et coll. 1974). The method is based on attenu-

Table 5 (cont.)

Cortical thickness & radius	Inner diameter		Cortical res			
	Mc Il	Rad	Fem	Mc Il	Rad	Fem
—	—	—	—	—	—	—
0.28	—	—	—	—	0.30	—
0.37	-0.95	-0.50	-0.29	—	—	—
—	-0.36	-0.53	-0.29	—	-0.30	—
0.33	-0.35	-0.33	-0.06	—	—	0.46
1.0	-0.30	-0.33	-0.37	—	0.84	—
-0.30	1.0	0.49	0.28	—	—	—
-0.33	0.49	1.0	0.32	—	—	—
-0.37	0.28	0.32	1.0	—	—	—
—	—	—	—	1.0	—	—
0.84	—	—	—	—	1.0	—
—	—	—	—	—	—	1.0

tion measurements employing a scintillation detector the attenuation of the soft tissues in the radiation beam was compensated by using two radiation energies. The mineral content at a particular site was determined by scanning with a xrt beam that was well collimated. Measurements were made at eight sites to obtain a representative appearance of the whole skeleton. These and the precision obtained appear in Table 2 (cf DALÉN & JACOBSON 1975).

A normal population was examined to assess the extent to which the methods enable small differences in osteoporosis to be distinguished. The group was drawn at random from Stockholm: the proportion of missing subjects totalling 27 per cent. The age distribution of the material measured was as follows: Women, age 30-34 $n=24$ 45-49 $n=20$ 55-59 $n=28$ Men, age 45-49 $n=10$ 55-59 $n=14$.

Some parameters, such as the mineral content and areas of cortical bone, are dependent on body size, while others such as the grading of trabecular bone and the cortical ratios, are not. To make these parameters comparable all the values dependent on body size were divided by the body area as calculated from $(\text{height (cm)} + \text{weight (kg)} - 60)/100$.

All correlation coefficients except those given in Table 8 were obtained after correction for age, sex and body size. The corrections for age and sex were

Table 6

Spearman Rank Correlation coefficients between bone mineral content at various measuring sites. The values were corrected for age, sex and body size before the coefficients were calculated

	Meta- carpal bone II	Radius + ulna		Humerus head	Third lumbar vertebra	Femur		Calcaneus
		Distal	Shaft			Neck	Shaft	
Metacarpal bone II	1.0	0.63	0.72	0.52	0.31	0.42	0.30	0.29
Radius + ulna distal	0.63	1.0	0.75	0.62	0.35	0.59	0.35	0.46
Radius + ulna shaft	0.72	0.75	1.0	0.53	0.33	0.45	0.44	0.29
Humerus head	0.52	0.62	0.53	1.0	0.30	0.6*	0.31	0.50
Third lumbar vertebra	0.31	0.33	0.33	0.30	1.0	0.4	0.18	0.30
Femur neck	0.4	0.59	0.45	0.62	0.42	1.0	0.51	0.43
Femur shaft	0.30	0.35	0.44	0.31	0.18	0.51	1.0	0.51
Calcaneus	0.29	0.46	0.29	0.30	0.30	0.43	0.51	1.0

made by expressing each value for each subject as the percentage deviation from the mean for the respective age and sex group.

Results

The morphologic parameters differed according to sex and age and to facilitate their comparison the values were expressed as a percentage of the mean for the youngest female group. The results are presented in Table 3. At ages as low as 45–49 years both sexes displayed morphologic signs of osteoporosis in the form of sparse trabecular structure in the lumbar spine and the femoral neck, while females also had wide marrow spaces in the long bones.

The mineral content also differed according to sex and age (Table 4). The biologic variation was greater for the trabecular than the cortical measuring sites. The lowest values for the bone mineral content in the 55–59 year group of women were recorded for the distal parts of the radius and ulna, head of the humerus and the central part of the femoral neck. The sex differences for respective age groups were large for the upper extremities but small for the lumbar spine and femoral neck.

The coefficients of correlation (BMDP 3S) between the various morphologic parameters were generally low (Table 5). The grading of trabecular structure in the femoral neck was the only parameter significantly correlated ($p < 0.01$) to the estimated degree of osteoporosis of the lumbar spine. The coefficients of correlation (BMDP 3S) between the values for the mineral content at the various measuring sites (Table 6) were considerably higher than the coefficients for the morphologic parameters. The relationship between these parameters and the bone mineral content appears in Table 7. The mineral content for the

Table 7

Spearman Rank Correlation coefficients between morphologic parameters and mineral content. All coefficients between -0.15 and 0.25 are omitted. The values were corrected for age and body size before the coefficients were calculated.

	Meta- carpal bone II	Radius+ulna Distal Shaft	Hume- rus head	Third lumbar verte- bra	Femur Neck Shaft	Calca- neus
Lumbar spine trabecular score	—	0.27	—	0.33	—	0.29
Femur neck trabecular score	—	0.43	0.25	0.30	—	0.33
Metacarpal II cortical ratio	0.26	0.30	—	—	—	—
Radius cortical ratio	—	—	—	—	—	—
Femur cortical ratio	—	—	—	0.25	0.29	0.43
Radius cortical thickness	0.51	0.48	0.58	0.34	—	0.40
Metacarpal II cortical area	0.63	—	0.37	—	—	—
Radius cortical area	0.51	0.47	0.60	0.43	—	0.36
Femur cortical area	—	—	—	—	0.26	0.53

trabecular measuring sites in the distal parts of the radius and ulna, the head of the humerus and the femoral neck are correlated to some extent with the trabecular structure in the lumbar spine and femoral neck. A fairly close correlation between the cortical area and the bone mineral content of the second metacarpal bone was evident (cf. VERGARA & MIKHOLEN 1960).

Table 8

Spearman Rank Correlation coefficients between morphologic parameters, mineral content and age for females. The morphologic parameters and the mineral content were not corrected for age.

	Meta- carpal bone II	Radius+ulna Distal Shaft	Hume- rus head	Third lumbar verte- bra	Femur Neck Shaft	Calca- neus	Years
Lumbar spine trabecular score	0.42	0.64	0.47	0.68	0.50	0.5	—
Femur neck trabecular score	0.47	0.62	0.41	0.62	0.48	0.50	—
Metacarpal II cortical ratio	—	—	—	—	—	—	—
Radius cortical ratio	—	—	—	—	—	—	—
Femur cortical ratio	—	—	—	—	—	—	—
Radius cortical thickness	—	—	—	—	—	—	—
Metacarpal II cortical area	—	—	—	—	—	—	—
Radius cortical area	—	—	—	—	—	—	—
Femur cortical area	—	—	—	—	—	—	—
Years	—	—	—	—	—	—	—

Trabecular bone presented a greater correlation with age than cortical bone. This is evident in Table 8 in which the correlation between morphologic parameters, bone mineral content and age for the female group is given.

Discussion

The morphologic findings (Table 3) are consistent with what is known of the occurrence of osteoporosis in various sex and age groups. Both microradiography and autopsy have indicated that osteoporosis is of early onset, probably developing by the fourth decade in both sexes (LINDAHL & LINDORSEN 1962, JOWSEY *et al.* 1965). In one of the few longitudinal investigations performed, GARN *et al.* (1967) have reported that cortical bone is remodelled by endosteal resorption and periosteal apposition, a process that results in an increase in the inner and outer diameters with age.

The reduction in the mineral content with age was greater in trabecular than in cortical bone. The oldest female group had particularly low mineral contents in the distal parts of the radius and ulna, the humeral head and the central part of the femoral neck; these sustain a high incidence of fractures (ALFGRAM & BAUER 1962, ALFGRAM 1964). Another agreement between fracture epidemiology and bone mineral content is evident from the sex differences observed. Consequently, men have comparatively less fracture incidence in the distal part of the radius than in the femoral neck, as compared to females; the sex differences in bone mineral content (Table 4) may explain these differences in bone brittleness.

The morphologic parameters and the bone mineral content did not always correspond. For instance, the inner diameter of the long bones increased considerably with age, but the differences in their mineral content in the various age groups were small (Tables 3, 4). One possible explanation of this discrepancy between the morphologic evidence of bone loss and the decrease in the bone mineral content is that endosteal resorption is to some extent compensated for by periosteal apposition. The latter results in an increase in the outer diameter and a reduction in the amount of bone mineral per unit of anatomic volume, even when the mineral content remains unchanged.

The choice of a measuring site is of importance. This is illustrated by the bone mineral content of the femoral neck recorded, whereas the changes with age were small for the medial cortical part, they were considerable for the central trabecular part.

The coefficients of correlation between the various morphologic parameters were generally low. It is consequently at most sites difficult to estimate the grade of osteoporosis from morphologic observations at another site. The grading

of trabecular structure in the femoral neck was the only parameter significantly correlated ($p < 0.01$) to the estimated degree of osteoporosis of the lumbar spine.

Certain trends may be discerned in the correlations between the bone mineral content for the various measuring sites (Table 6). For example the closer the sites were to each other the greater the correlation. Moreover the trabecular bone measurements agreed with one another and the cortical bone measurements had a tendency to correlate internally; this is consistent with the results of Norman (1968). The bone mineral content of the third lumbar vertebra however would seem to constitute an exception but here the major part of the mineral content of the vertebra is accounted for by the transversal and spinous processes which contain a greater proportion of cortical bone than the body. Spondylosis may also be a significant factor.

The mineral content in the trabecular parts of the skeleton had the greatest correlation with morphologic signs of osteoporosis as indicated by sparse trabecular structure in the axial skeleton and wide marrow spaces in the appendicular bones (Tables 7-8).

Acknowledgement

This work was supported by a grant from the Swedish Medical Research Council.

SUMMARY

An investigation of randomly selected subjects by skeletal roentgenology and bone scanning revealed that the mineral reduction with age is greater in trabecular than in cortical bone. The amount of mineral in the oldest female group was especially low in parts of the skeleton with a high incidence of fractures (distal part of radius proximal part of humerus and the femoral neck). The mineral content of these sites had the greatest correlation with morphologic signs of osteoporosis.

ZUSAMMENFASSUNG

Eine Untersuchung zufällig ausgewählter Personen mit Röntgenuntersuchung des Skeletts und Knochenzählung ergab, dass die Abnahme an Mineralien mit dem Alter stärker im trabekulären Knochen als im kortikalen Knochen ausgeprägt war. Der Mineralgehalt in der ältesten weiblichen Gruppe war besonders in den Teilen des Skeletts niedrig, bei denen das Vorkommen von Frakturen hoch ist (dem distalen Teil des Radius, dem proximalen Teil des Humerus und dem Femurhals). Der Mineralgehalt dieser Gebiete zeigte die höchste Korrelation zu den morphologischen Zeichen einer Osteoporose.

RÉSUMÉ

Un travail fait sur des sujets choisis au hasard effectué par radiographie du squelette et par scintigraphie osseuse a montré que la réduction du contenu minéral en rapport avec l'âge est plus grande dans l'os trabéculaire que dans l'os cortical. La teneur en minéraux dans le groupe des femmes les plus âgées était particulièrement faible dans les parties du squelette qui présentent une grande fréquence de fracture (la partie distale du radius, la partie proximale de l'humérus et le col fémoral). La teneur minérale de ces régions présentait la plus grande corrélation avec les signes morphologiques d'ostéoporose.

REFERENCES

- ALFRAIM P. A. An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population. *Acta orthop scand* (1964) Suppl No 63
- and BAUER G. C. H. Epidemiology of fractures of the forearm. *J Bone Jt Surg* 44 A (1962) 105
- BARNETT E. and NORDIN B. E. C. The radiological diagnosis of osteoporosis: A new approach. *Clin Radiol* 11 (1960) 166
- BIOSTATISTICAL COMPUTER PROGRAMS BMDP 35 Spearman Rank Correlation. University of California, Los Angeles 1971
- DALEN N. and JACOBSON B. Bone mineral assay: Choice of measuring sites. *Invest Radiol* (in press)
- GARN S. M., ROITMAN C. G., WATNER B. and ASCHER W. Continuing bone growth throughout life: A general phenomenon. *Amer J phys Anthropol* 26 (1967) 313
- GUSTAFSSON L., JACOBSON B. and HILSOFREY L. X-ray spectrophotometry for bone mineral determinations. *Med Biol Eng* 12 (1974) 113
- JACOBSON B. X-ray spectrophotometry in vivo. *Amer J Roentgenol* 91 (1964) 202
- JOWERY J., KELLY P., RIGGS L., BLALOCK A., SCHOLE D. and GRANTON C. Quantitative microradiographic studies of normal and osteoporotic bone. *J Bone Jt Surg* 47 A (1965) 785
- LEVYDAHL O. and LINDGREN Å. O. H. Grading of osteoporosis in autopsy specimens. *Acta orthop scand* 32 (1962) 85
- MAXINE R., CAMERON J. and SORRELLS J. A comparison of radiological methods for determining bone mineral content. I. Progress in methods of bone mineral measurement. p. 435. Dept. HEW, NIH, NIAMD, Bethesda 1968
- MEKMA H. E. Cortical bone atrophy and osteoporosis as a manifestation of aging. *Amer J Roentgenol* 89 (1963) 1287
- NORDIN B. E. C. Bone patterns in aging and osteoporosis. In: Progress in methods of bone mineral measurements. p. 159. Dept. HEW, NIH, NIAMD, Bethesda 1968
- SAVILLE F. D. A quantitative approach to simple radiographic diagnosis of osteoporosis: its application to the osteoporosis of rheumatoid arthritis. *Rheum Arth* 10 (1967) 416
- STOUT M., NAGRAATH A. R. and MAHLE P. S. Changes in trabecular pattern of the upper end of the femur as an index of osteoporosis. *J Bone Jt Surg* 52 A (1970) 457
- VIETAMA P. and MAJLUND H. Thickness of the cortical layer as an estimate of mineral content of human finger bones. *Brit J Radiol* 33 (1960) 60

INSTRUMENT FOR ISOTOPE DETERMINATION IN VIVO OF MINERAL CONTENT OF THE JAW BONE

N BJÖRA, S ELIASSON, J E FALL and C O HENRIKSSON

Advanced photodensitometric methods for the roentgenographic determina-
tion of the mineral content of bone were published by ERIKSSON & WELIN
(1949) OWELL (1957) et alios Transmission measurement from an isotope
by direct photon absorptiometry has recently come into increasing use and
provided for greater precision and accuracy than previously The isotope ^{45}Ca
was introduced as a radiation source for diagnosis by BERGMAN et coll (1962)
this isotope was also employed by CAMERON & SORESENSEN (1963) to determine
the quantity of bone mineral Since then a large number of determinations of
bone mineral have been reported other isotopes have also been employed
(SCHMELING 1972) HENRIKSSON (1967) described how measurements of high
precision may be made of bone mineral in the jaws by fixation of the source of
radiation to the teeth A device for this purpose was developed by HENRIKSSON
& JULIN (1971)

The object of the present work has been to design an instrument for the
quantitative measurement of bone mineral in the jaws and alveolar processes
the determination of the jaw thickness being made during the transmission

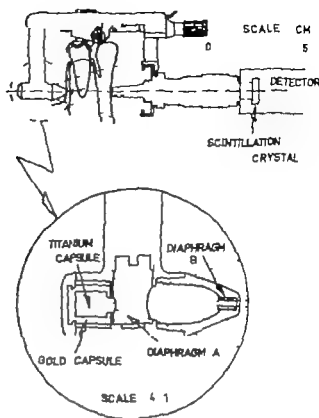


Fig 1 Drawing of the instrument with enlarged section of the capsule containing isotope and diaphragm system

measurement without disturbance of the latter by saliva, fluctuating swellings or mobile mucosa. The device had also to offer the means of identifying the area of the transmission measurement so as to make it possible to assess the relationship of the measurement to surrounding anatomic structures in a roentgenogram.

Method The attenuation of roentgen radiation through bone and soft tissue is caused partly by bone minerals and partly by protein, fat and water. Disregarding the small fat component it may be assumed that—apart from the bone mineral—attenuation takes place mainly in protein and water, the linear attenuation coefficient of which has been given by HENRIKSSON & JULIN (1971) as 0.45 cm^{-1} at a radiation energy of 27.4 keV (I) in gingivae. The linear attenuation coefficient for the bone mineral constituents was reported by the same authors to be 9.4 cm^{-1} .

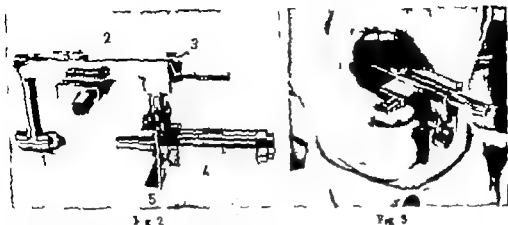


Fig. 1) Capsule with isotope rotatable diaphragm A and fixed diaphragm B 2) Base for base columnal and meridional movement with macro-metric screws 3) Operating lever for rotatable diaphragm A 4) Macro-metric screw for thickness measurement and connection to detector 5) Film holder

Fig. 2 The instrument in situ for exposure of film

The transmission formula may be expressed as

$$T = \frac{I_1}{I_0} = e^{-(\mu_b x + \mu_s (l-x))}$$

where T = the transmission

I_0 = the flow of photons into the object

I_1 = transmitted flow of photons

e = the base of the natural logarithm system

μ_b and μ_s = linear attenuation coefficients for bone mineral and soft tissue (cm⁻¹)

l = total thickness of the object (cm)

x = thickness of hydroxyapatite

If the linear attenuation coefficients for the given radiation energy are known three values are required for determination of bone mineral (1) Flow of photons in front of the tissue, I_0 (2) transmitted flow of photons I_1 and (3) total thickness of tissue l . Correction for the effect on the attenuation coefficient caused by small amounts of radiation of energies other than the major part of the radiation is done after the recording of the spectrum for the radiation source and the construction of a correction curve (HARRISON & BERGSTRÖM 1973).

The flow of photons from a well collimated narrow beam may be counted with a detector analyser counter system. A device has been constructed with a holder for the isotope and diaphragm system and permitting measurement of thickness



Fig. 1. Frontal view of the instrument.



Fig. 2. The instrument in situ with the detector connected.

by means of a micrometer screw (Figs 1, 2). The instrument consists of three main parts: (1) Capsule with isotope and diaphragm system, (2) base moved by micrometer screws in buccolingual and mesiodistal directions, (3) film holder and micrometer screw for measurement of thickness. The capsule and film holder with micrometer screw are rigidly secured to the base.

The capsule contains an isotope, e.g. ^{131}I electrolytically precipitated on the tip of a silver or copper electrode of 0.5 mm diameter (BERGSTRÖM *et al.* 1962, 1972). (This isotope is supplied by AB Atomenergi enclosed in a titanium capsule 3 mm ϕ and 4 mm long.) The titanium capsule is enclosed in a gold shield with screwcap and with a window open in the direction of the beam. Thin radiation filters, e.g. of tin, may be inserted in the window. The gold shield is enclosed in the instrument capsule with another screwcap. A rotatable diaphragm A lies in front of the window in the direction of the beam. This has three settings, a first setting with a large aperture for exposure of the film and a second setting to produce a small aperture at 90° to the large aperture for the transmission measurement. The latter aperture produces a beam slightly wider than the inner diameter of diaphragm B which thus determines the diameter of the beam from the instrument capsule. Diaphragm B is fixed to the instrument capsule with a plastic cone. The distance from the isotope to the tip on the plastic cone is 16 mm. Diaphragm B on exposure of the film appears as a ring round the area measured (Fig. 1). The rotatable diaphragm A of gold has an intermediate setting between the two mentioned at which the beam is entirely cut off. This diaphragm is controlled by an adjusting lever outside the oral cavity (3, Fig. 2).

The photon flux
holder and micro-

of the object
w for me

examination reach the cassette
t of the thickness of the jaw

On exposure of film a bayonet socket enables the micrometer screw to be removed (Fig 3). The base is screwed buccolingually for the transmission measurement so that the plastic cone at diaphragm B is applied to the tissue lingually. A probe with a thin plastic window is then screwed against the tissue buccally so that the total thickness of the tissue may be read directly on the micrometer screw. The size of the plastic window is so adjusted as to contain the entire beam. The transmission measurement is thus made, the detector being brought up against a guide ring at the far end of the hollow micrometer screw (Fig 5).

A silver splint to which is fixed a plate with two pins attaches the device to the jaw (HEXMERSON 1967). The isotope capsule is sealed against the entry of liquid, e.g. saliva. The device is mostly of stainless steel with teflon bushings and seals. Autoclaving is possible: the isotope with the gold capsule should first be removed through the screw cap in the rear end of the capsule followed by the plastic cone with diaphragm B and the plastic window in the probe. The plastic cone and window are attached by means of conical seatings.

Discussion

The instrument has been based on the same principles as those described by HEXMERSON (1967) and HEXMERSON & JONES (1971). The latter stated that the thickness measurement was done by bringing the buccal and palatal windows of the device, spaced at a fixed distance from one another, up against the tissue one at a time so that its total thickness might be calculated. This procedure assumes that the measurement be made against firm gingiva or mucosa on each side and that saliva will cause no impediment to the beam: the measurement must therefore be made in areas of firm mucosa and after careful air drying.

The present device was constructed for measurements also of the lower jaw where accumulation of saliva, mobile mucosa and if therapeutic measures have been taken, fluctuating swellings may occur. Thin plastic windows applied to the mucosa on each side during the measurement help to prevent these factors affecting the result. Swellings of the soft tissue may be displaced with the windows so that in repeat examinations a constant thickness of object may be obtained despite the disappearance or fluctuation of the swellings.

As the radiation from ^{251}I may also be used for roentgenography the instrument was constructed to allow the production of roentgenograms. A bulb diaphragm marks the exact area used for the transmission measurement. This permits a reliable assessment of the area of the bone mineral measured and of its situation in relation to surrounding anatomic structures.

Acknowledgement

The authors are greatly indebted to Dr Sevald Forberg for his help during the work

SUMMARY

A device for measurement of the bone mineral in the jaws is described. The transmission of a narrow beam of radiation from an isotope is measured. Windows applied to the mucosa on both sides of the object permit the determination of thickness to be made without disturbance from saliva or mobile tissue. Roentgenography of the region under examination is made possible and is a feature of the instrument.

ZUSAMMENFASSUNG

Eine Anordnung zur Messung des Knochenmineralgehalts der Kiefer wird beschrieben. Die Transmission eines feinen Strahls der Strahlung von einem Radionuklid wird gemessen. Fenster die an die Mukosa zu beiden Seiten des Objekts angebracht werden ermöglichen die Dicke ohne Störung durch Speichel oder bewegliches Gewebe zu messen. Die Röntgenuntersuchung der Region während der Untersuchung ist möglich und ein Merkmal des Instruments.

RÉSUMÉ

Description d'un dispositif de mesure du contenu minéral de los des maxillaires. On mesure la transmission d'un étroit faisceau du rayonnement d'un radionucléide. Des fenêtres appliquées à la muqueuse sur les deux faces de l'objet permettent de déterminer son épaisseur sans erreur due à la salive ou aux tissus mobiles. La radiographie de la région examinée est possible et est une des caractéristiques de cet instrument.

REFERENCES

- BERON, P., TOSSIGN, S., HENRIKSSON, C. O. and SOREMARK, R. The use of iodine 125 as an x-ray source in roentgen diagnostics. *Int. J. appl. Radiat.* 13 (1962) 255.
- , JOHANSSON, B. and SOREMARK, R. Electrodeposition of point Cu^{64} roentgen sources. AE-462 AB Atomenergi, Studsvik 1972.
- CANNON, J. R. and SOREMARK, J. Measurement of bone mineral in vivo. An improved method. *Science* 112 (1963) 230.
- ENGBLOM, A. and WELIN, S. A method for the quantitative roentgenological determination of the amount of calcium salts in bone tissue. *Acta radiol.* 31 (1949) 483.
- HENRIKSSON, C. O. Iodine 125 as radiation source for odontological roentgenology. *Acta radiol.* (1967) Suppl. No. 269.
- and JULIN, P. Iodine 125 apparatus for measuring changes in x-ray transmission and the thickness of alveolar process. *J. Periodont. Res.* 6 (1971) 152.
- and BECKSTRÖM, J. Quantitative longitudinal study of alveolar bone tissue in man. II. Accuracy and precision of alveolar bone mineral mass determination by iodine-125-absorptiometry. To be published.
- OWELL, L. A. Quantitative roentgenologic studies on changes in mineral content of bone in vivo. *Acta radiol.* (1957) Suppl. No. 148.
- SCHMELING, P. Measurement of bone mineral content using radiation sources. An annotated bibliography. AE-454 AB Atomenergi, Studsvik 1972.

ANGIOGRAPHY IN GASTRIC TUMOURS

F EYSEY and H. FISCHERMAN

The detection of gastric malignancy has for many years constituted a challenge calling for many different procedures. For the early diagnosis, the conventional barium meal is improved by the double contrast investigation and gastroscopy including biopsy is now well established. Selective angiography of the coeliac and superior mesenteric arteries have also contributed to the diagnosis (Borjesson et coll 1966). selective angiography of the left gastric artery has been discussed by SUNDQVIST (1970) who stressed its value in small lesions.

The present investigation was carried out in order to compare the results of angiography with those of surgery as regards the size of the tumour and its resectability. the vascular appearance of the process was also compared to the histologic type.

Material and Methods The series comprised 15 consecutive patients aged from 44 to 82 (average 63 years) with gastric carcinoma. Before angiography malignancy had been diagnosed by a conventional barium meal including the double contrast method. Gastroscopy with biopsy as well as the pentagastrin test were carried out if technically possible.

Submitted for publication 6 July 1973

Table I

Resectability and angiographic findings in 15 cases of gastric carcinoma. Figures indicate number of cases with positive angiographic findings

	N of cases	Angiographic findings of coeliac art.					Superior mesenteric art.				
		A	B	C	D	E	A	B	C	D	E
Resectable	7	4	3	7	6	4	1	2	2	1	0
Non resectable	6	1	4	3	5	2	0	0	1	0	1
No operation	2	0	0	0	2	2	0	0	0	0	0

A Displacement of major artery

B Irregularities of major artery wall

C Change of calibre in small arteries

D Parenchymatous accumulation of contrast medium

E Increased thickness of the gastric wall

A preshaped polythene catheter (MIDAELOSSON 1965) was introduced transfemorally under local anaesthesia and 25 to 30 ml sodium iothalamate (Conray 400) were injected into the coeliac artery at 10 to 12 ml per second. Frontal and oblique films (right or left shoulder elevated) were usually obtained. The superior mesenteric artery was examined with 20 ml of contrast medium and frontal roentgenograms. The length of the series was over 30 seconds at least so as to include the late venous phase, especially in the portal vein. The stomach was distended in 9 patients by means of an effervescent tablet swallowed before the angiography. Unsuccessful attempts were made in 4 additional patients to inject contrast medium into the left gastric artery with a MIDAELOSSON catheter furnished with a curved up 2 cm longer than normal. The angiographies were evaluated according to the criteria in Table I.

Results

Operation confirmed a gastric tumour in 13 patients, this being revealed in the remaining 2 patients by autopsy and gastroscopy respectively. The tumour was removed in 7 patients (Table I). The angiographies failed to supply information regarding operability.

The tumour size measured at operation and the pre operative angiography were compared (Table 2): no growths below 3 cm in diameter were present in

Table 2

Angiographic changes in 15 patients with gastric neoplasms related to its size

Size of tumour	No. of cases	Angiographic findings					Superior mesenteric art.				
		Coeliac art.									
		A	B	C	D	E	A	B	C	D	E
0-3 cm	0										
3-5 cm	3	2	2	2	2	1	1	1	1	1	0
Over 5 cm	6	2	4	3	3	3	0	0	0	0	0
Whole stomach	4	1	1	3	4	0	0	1	2	0	1
No operation	2	0	0	0	2	2	0	0	0	0	0

One patient with benign lesion
A to E see Table 1

the material. The small number of cases in each group prevented any statistical evaluation of the correlation between tumour size and the angiographic findings. However, the most constant angiographic sign in all sizes was a change in the calibre of small arteries and parenchymatous accumulation of contrast medium. The latter sign was also present in one of the patients with a benign tumour. The group of gastric tumours more than 5 cm in diameter had more extensive angiographic changes than those of the group of smaller tumours.

No correspondence was evident between the macroscopic and angiographic sizes of the tumours.

As stated, a comparison was made of the angiographic findings and the histologic type of tumour (Table 3). Sarcomatous tumours (reticulosarcomas and leiomyomas) presented few changes compared to carcinomas. The different types of carcinoma could not be identified angiographically.

The angiographic changes A to E most frequently lay in the coeliac artery, while those in the superior mesenteric artery were rare (Tables 1, 2 and 3).

No complications were noted apart from a few instances of small and insignificant haematomas at the femoral puncture.

Selective angiography of the left gastric artery. It was impossible in 4 out of 15 to manoeuvre the tip of the catheter freely in the coeliac artery in order to inject it into the origin of the left gastric artery. No angiographic series were obtained. The coeliac axis was found at operation to be stenotic due to malignant infiltration.

Table 3

Angiographic changes in 15 patients with gastric neoplasm related to histologic findings

Type of tumour	N of cases	Angiographic findings Coeliac art.					S. perior mesenteric art.				
		A	B	C	D	E	A	B	C	D	E
Adenocarcinoma	6	3	3	5	5	4	0	1	1	0	0
Adenoid solid carcinoma	3	1	2	1	3	3	0	0	0	0	0
Colloid carcinoma	2	0	1	2	2	0	0	0	1	0	0
Anaplastic carcinoma	1	0	1	1	1	0	1	1	1	1	0
Reticulosarcoma	2	0	0	0	2	1	0	0	0	0	1
Leiomyoma (benign)	1	1	0	1	0	0	0	0	0	0	0

A to E see Table 1

Discussion

It is commonly accepted that angiography is of minor value in the diagnosis of gastric neoplasms (ALLEN et coll 1971). As the latter pointed out, this procedure adds little to the information gained by barium and endoscopic examinations. A possible indication for angiography could be the evaluation of the extent of a gastric neoplasm, establishing a preoperative measure of its operability. The present investigation revealed that neither this nor an estimation of the size was possible even by a detailed assessment of the angiographic changes. The general impression was that the changes in fact tended to underestimate the tumour size revealed at operation. The change of calibre in small arteries was evident only in a limited area of even a large tumour.

The changes were almost exclusively in the coeliac artery and its branches, while those in the superior mesenteric artery were insignificant. This is in keeping with the statement by BOJSEN et coll. that the arterial supply for the stomach is largely derived from the coeliac artery.

Angiography in the diagnosis of small gastric tumours has been advocated by SUNDORF. As no cases of early gastric carcinoma were present in the present work, no opportunity arose for the method to be evaluated under these particular circumstances. Selective angiography of the left gastric artery could not be performed with the large masses as the process had propagated to the coeliac axis to make catheterization impossible.

Carcinomas ranging from scirrhous to anaplastic tumours produced all types of angiographic abnormalities however without any correlation between vascular

changes and histology. Both a reticulosarcoma and a leiomyoma were accompanied by discrete angiographic alterations.

The present investigation has indicated that angiography of the large arteries supplying the stomach in confirmed gastric malignancy adds no further information to the estimation of size and operability even with a detailed evaluation of the vascular changes.

SUMMARY

Pre-operative coeliac and superior mesenteric angiographies were carried out in 15 cases of histologically verified gastric tumours. No correspondence was evident between the macroscopic and angiographic sizes. In a tumour neither could the resectability be estimated by angiography. No correlation between the angiographic appearance and the histology type of neoplasm was apparent.

ZUSAMMENFASSUNG

Präoperative Angiographien der coeliacalen und der oberen Mesenterialarterien wurde bei 15 histologisch nachgewiesenen Fällen eines Magentumors vorgenommen. Es fand sich keine Übereinstimmung zwischen der makroskopischen und der angiographischen Tumorgroße, auch die Resektierbarkeit konnte nicht durch die Angiographie bestimmt werden. Es fand sich keine Korrelation zwischen dem angiographischen Bild und dem histologischen Typus des Neoplasmas.

RÉSUMÉ

Les auteurs ont fait des angiographies coeliaques et mésentériques supérieures préopératoires dans 15 cas de tumeur de l'estomac, prise histologiquement. Ils n'ont pas trouvé de correspondance évidente entre les dimensions macroscopiques et angiographiques d'une tumeur. L'angiographie n'a pas permis non plus d'apprécier l'opérabilité. Il n'y avait pas de corrélation apparente entre l'aspect angiographique et le type histologique de la néoplasie.

REFERENCES

- ALLEN C R, FISHER R G, GORTON D K and HARRIS T. Clinical application of selective gastrointestinal angiography. *T J M d* 67 (1971) 54.
- BORJESON E, WALLACE S and HARRIS T. Angiography in tumours of the stomach. *Acta radiol* Diagnosis 4 (1966) 306.
- VIDAARLUND C O. Polythene catheter for percutaneous selective catheterization of gastric artery. *Acta radiol* (1970) 5 suppl 299.

AORTA, HEART AND LUNG VESSELS IN IDIOPATHIC PULMONARY EMPHYSEMA RELATED TO PULMONARY FUNCTION

BJORN NORDENSTROM and TATSUO KUMAZAKI

This investigation was prompted by the observation that the heart appears unusually small and the aorta abnormally wide in a certain type of pulmonary emphysema often called diffuse or idiopathic emphysema. It was felt that these cardiovascular changes and the actual type of emphysema may be considered as manifestations of a common pathogenetic factor. The complexity makes a brief survey of certain relevant facts and limiting factors necessary for an understanding of the methods applied and the discussion of the results.

Emphysema is classified (but slightly modified) according to Reid in Fig. 1. The idiopathic type of emphysema may be divided into centrilobular and panlobular in which the retractive forces of the lungs are decreased due to the loss of parenchyma (CHRISTIE 1934, STEAD et coll. 1952, McLEAN 1956, 1958, PIERCE & EBERT 1958, PIERCE et coll. 1959, 1961, HEARD 1960, MENKELY et coll. 1962, GIESE & HARTUNG 1964, REID 1964, FITZPATRICK 1967).

CUDKOWICZ & ARMSTRONG (1953) reported obliteration of the intrapulmonary bronchial arteries in diffuse atrophic emphysema. The central pulmonary arteries and bronchi however were well supplied with systemic arterial blood.

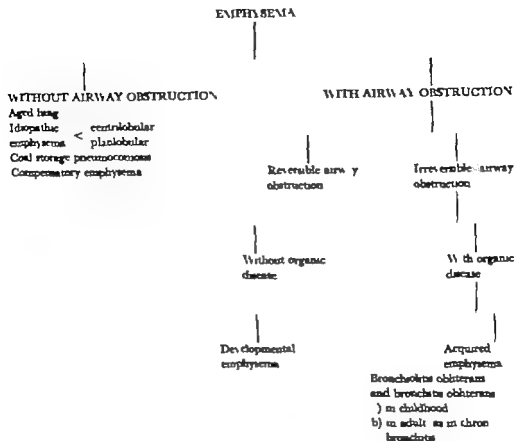


Fig. 1. Classification of emphysema (partly after Rimm 1964)

from large precapillary anastomoses communicating with the vasa vasorum of the pulmonary arteries (which are derived from the bronchial arteries).

Centriobular emphysema (LEOPOLD & GOUGH 1957, LEOPOLD & SEAL 1961, WYATT et coll. 1964 a, b, THURLBECK 1967) is characterized by a central loss of tissue with the periphery of the secondary lobules well preserved. The abnormalities are predominately developed in the apical anterior and posterior segments of the upper lobes and apical segments of the lower lobes and in the early stages mostly in the subpleural parts of the lungs.

Panlobular emphysema or as it is sometimes termed panacinar emphysema (WYATT et coll. 1962, 1964 a, b, THURLBECK 1967) is characterized by a uniform distribution of air sacs throughout the secondary lobules of the whole lung.



Fig 2 Idiopathic emphysema with a small heart and a large aorta. The three dimensions for the measurements of heart volume are indicated.

The heart has been much investigated in pulmonary emphysema; it has often been stated that the right ventricle is enlarged when the condition is advanced (WYATT *et coll* 1964 b); the examinations were largely performed post mortem. It would appear however that the right ventricle as well as the whole heart is, in the living, seldom enlarged in advanced cases of uncomplicated emphysema. MOUNSEY (1954), CROMIE (1961), HICKEN *et coll* (1966), CULLEN *et coll* (1970), OUTHRED *et coll* (1970), EDWARDS *et coll* (1971) have also stressed that no association between right ventricular hypertrophy and the grades of emphysema was present in their post mortem material. FORAKER *et coll* (1970) reported that autopsies had indicated that the left ventricular myocardial coronal area was strikingly diminished in severe emphysema, both absolutely and relatively to total ventricular myocardium. The left ventricular cavity was also smaller in advanced emphysema; this premise was supported by FISHMAN (1971).

A comparison between heart volume determinations by radiology in emphysema and non-emphysema patients appears not to have been made. Most publications on cardiac size in emphysema of the living are unfortunately based only on measurements of the frontal projection of the heart in chest films and are therefore inconclusive.

The observation that patients with extensive generalized emphysema have an abnormally small heart and a large aortic arch diameter (large cross sectional area of the aortic arch) is illustrated in Fig 2. A small heart may well be explained by low circulatory volume in advanced emphysema. This and the absence of increased systemic blood pressure makes it, on the other hand, difficult to explain a wide aorta. It has also been observed that the left ventricle is usually small in size although it appears hypertrophic while the right ventricle *in vivo* in uncomplicated idiopathic emphysema is of normal size and shape. The



b

Fig 3 Idiopathic emphysema of the panlobular type a) p. b) anterior part and c) posterior part of right lung with fine pulmonary vessels in the whole lung some of the peripheral vessels are absent or displaced due to emphysema

dominating appearance of the p. a. lung structures are fine peripheral pulmonary vessels which due to the depth of the chest, overlap and give the impression of uniform distribution (Fig 3 a). The more representative oblique views indicate deviations of fine lung vessels or the absence of vessels known to be caused by emphysema blebs (Fig 3 b c). These abnormalities are present uniformly in both lungs and correspond to panlobular emphysema.

A right lung with peripheral vascular changes of the type present in centrilobular emphysema appears in Fig 4 with more advanced vascular change the upper than in the lower part of the same lung.

A clear distinction between the centrilobular and panlobular emphysema is often difficult to make. The two will be dealt with as one unit as both are subdivisions of the idiopathic type of emphysema.

The width of the thoracic aorta should normally correspond to the amount of blood pumped by the heart. A close relationship also exists between the cardiac size and the flow under normal circulatory conditions. The flow in idiopathic



Fig. 4 a) Idiopathic emphysema of the centralobular type in mostly the upper lateral part of the right lung. Considerable narrowing and displacement of the peripheral vessels. b) The vascular abnormalities are less apparent in the lower part of the lung.

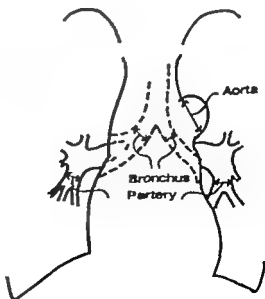


Fig. 5 The diameters of the right and left bronchi were measured about 2 cm distal to the carina. The diameters of the pulmonary arteries of the right and left lower lobes were measured in p.a. or oblique films above the origin of the local segmental artery.

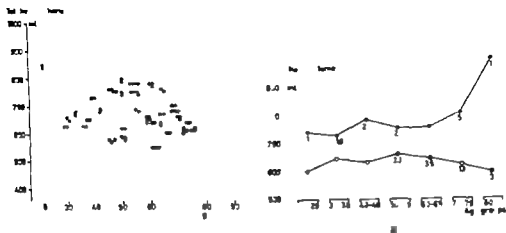


Fig 6 a) Total heart volume in males of different ages and b) mean heart volume. The heart is smaller in patients with diffuse emphysema (○) than in controls (●).

pulmonary emphysema is known to be small and the systemic pressure low or normal. Enlargement of the aorta in relation to heart size should therefore depend upon a quality change in the aortic wall with resulting increase in its diameter.

It was also thought that the abnormalities due to emphysema of the idiopathic type and the anticipated widening of the aorta might reflect a degenerative disease secondary to a common factor. The possible role of the bronchial arteries in the lung parenchyma and the vasa vasorum in the aortic wall will be treated in the general discussion. The small heart may well be secondary to diminished pulmonary function. Of certain interest in this connection are the observations that human working capacity is closely related to cardiac size (HOLMGREN & OVERTORP 1960, HOLMGREN *et coll.* 1960, EARLUND *et coll.* 1967).

Material and Methods. A total of 100 men and 50 women without clinical or unequivocal radiologic signs of emphysema were used as normal material for comparison. They were selected in age groups and number with anthropometric data (length and weight) as closely comparable as possible to those with emphysema.

As no physiologic function tests were available in the control material, function values were calculated indirectly by the methods of BERGLUN *et al.* (1963), BRATH *et coll.* (1963) and GRIMBY & SÖDERHOLM (1963).

The patients considered to have emphysema had been referred with this diagnosis or had clinical and radiologic signs of the disease. Complete data were available on the physiologic lung function tests. In all 99 men and 44 women

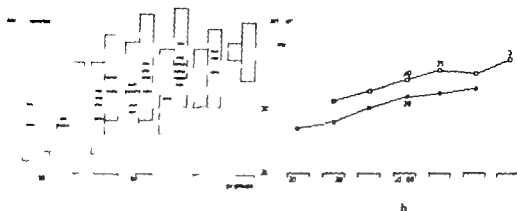


Fig. 7. a) Aortic arch diameter in males of different age groups and b) mean aortic arch diameter. The aorta is larger in the emphysema patients (O) than in the controls (●).

with the idiopathic type of pulmonary emphysema were examined radiologically. Those with localized bullous emphysema, other types of emphysema, diffuse lung conditions or signs of heart disease were excluded.

The roentgen examinations of the lungs were made in full inspiration at 180 kV in at least one series of p.a., lateral, 45° left and right anterior oblique positions and with one low kV (100 kV) p.a. film.

The heart volume was determined by the method described by LYSTOV & coll (1934), JONES & coll (1939), LILJESTRAND & coll (1939) with measurement of the long axis of the heart in the p.a. and the depth of the heart in the lateral view (Fig. 2). A standard correction factor of 0.42 was always used. The value of the total heart volume was obtained only in the erect position since the correction had to be made in relation to the diameters of the aorta.

The external aortic arch diameter was measured in the p.a. view in mm (Fig. 5). (See also ERTAT & coll 1965.) A barium swallow was sometimes employed to outline the medial border of the aorta. The measurements naturally often required variations in the exposure factors.

The diameters of the lower lobe pulmonary arteries were measured immediately below the origin of the apical segmental artery of the lower lobe on each side (Fig. 5).

The diameters of the left and right main bronchi were measured immediately above the origin of the upper lobe bronchi (Fig. 5).

A correlation factor (the cardio-aortic index) was calculated by dividing the heart volume with the aortic arch diameter.

The individual measurements in the material as well as the cardio-aortic indices were compared.

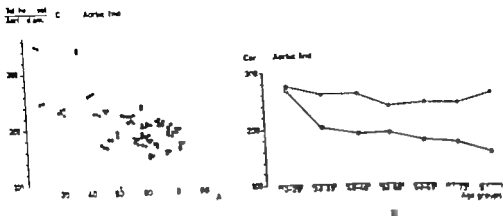


Fig 8 a) Total heart volume in ml divided by aortic arch diameter produces a relative heart volume termed the cardio-aortic index. This is lower in males with emphysema than in controls b) Mean cardio-aortic index in all males. This decreases with age and is lower in males with emphysema (○) than in controls (●)

The cardio-aortic indices were compared with the results of pulmonary function tests of inspiratory reserve volume, residual volume, forced expiratory volume as a percentage of total lung capacity, maximum voluntary ventilation in 40 seconds, residual volume to total lung capacity, and functional residual volume. All these were obtained from the routine clinical records.

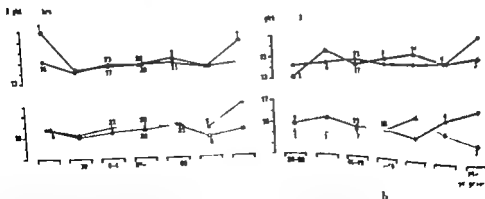


Fig 9 a) Mean diameter of right and left main bronchi. No obvious differences in males with emphysema (○) and controls (●) b) Mean diameter of the arteries of the right and left main bronchi. No obvious differences in males with emphysema (○) and controls (●)

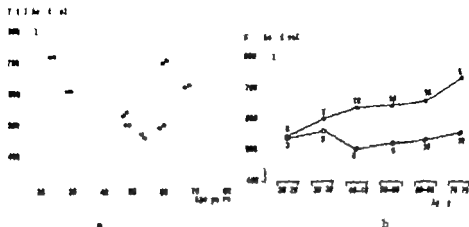


Fig 10 a) Total heart volume in the women with emphysema b) Mean heart volume in women the heart is smaller in those with diffuse emphysema (O) than in the controls (●)

Results

The total heart volumes of all the men have been plotted against age (Fig 6 a). The cases of emphysema have been grouped in the right lower part of the figure.

The same material was arranged in age groups against the mean heart volume in Fig 6 b the difference between the controls and the emphysema cases became even more obvious. The number of patients in certain age groups was small but the whole material presented a 15 to 20 per cent smaller total heart volume in the emphysema cases compared with that in the controls.

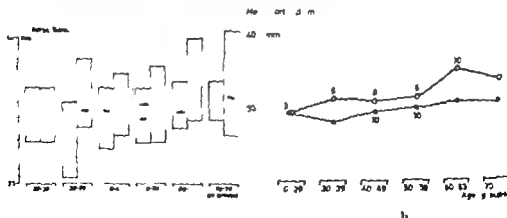


Fig 11 a) Aortic arch diameter in the women b) Mean aortic arch of greater diameter in the women with emphysema (O) than in the controls (●)

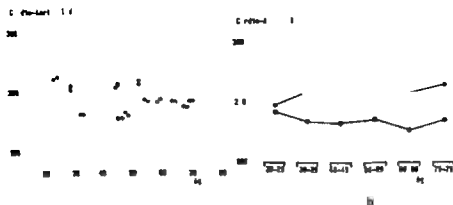


Fig. 12 a) Total heart volume (ml) divided by aortic arch diameter (cm) produces the cardio-aortic index lower in women with emphysema than in the controls b) The mean cardio-aortic index is lower in women with emphysema (O) than in controls (●)

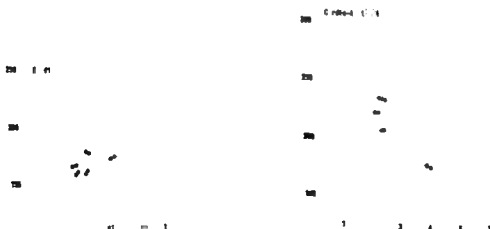


Fig. 13

Fig. 14

Fig. 13 Twenty seven males with diffuse emphysema of the lung. Relatively good direct correlation exists between the cardio-aortic index and the respiratory reserve volume.

Fig. 14 Differentiation between 25 males with emphysema (O) and the same number of controls (●) more easily obtained by the cardio-aortic index than by the corresponding values for the residual volumes (l).

200 150 100 50 0



Fig. 15

200 150 100 50 0



Fig. 16

Fig. 15 Good differentiation obtained between males with emphysema (O) and controls (●) by mean of the cardio-aortic index and the corresponding values for vital capacity (l).

Fig. 16 Relatively good linear relationship between the cardio-aortic index and forced expiratory volume (l) and mean age in 66 patients. The patients with emphysema (O males, Δ females) are distinctly separated from the controls (● males, ▲ females).

The diameters of the aortic arch as measured in mm in p.a. films are collected in age groups in Fig. 7a. The emphysema patients had a larger diameter than the controls which was more apparent when the mean diameter of the aorta was calculated (Fig. 7b). The diameter was increased with age in both the emphysema patients and the controls.

A cardio-aortic index was calculated by dividing the heart volume by the aortic diameter expressed in cm for each patient so as to obtain a comparable correlation factor. The ratios obtained were plotted against the ages (Fig. 8a). Most of the cardio-aortic indices of the emphysema patients appear in the lower half of the chart; the corresponding mean values are presented in Fig. 8b. A tendency for a lowering of the index with increasing age existed for both these and the controls.

A comparison was made between the mean diameters of the left and right main bronchi in all the patients (Fig. 9a). This produced the surprising result that no differences in calibre existed between the controls and the emphysema patients in the different age groups. Measurements of the mean diameters of the right and left lower lobe arteries suggested enlargement of the pulmonary artery on both sides, although in certain age groups this was not always apparent (Fig. 9b).



Fig 17



Fig 18

Fig 17 Integrated use of the cardio-aortic index and forced expiratory volume (l) as percentage of total lung volume separates the patients with emphysema (O males Δ females) and the controls (● males ▲ females)

Fig 18 Relatively good linear relationship between the index and the values for maximum voluntary ventilation during 40 seconds (O males Δ females with emphysema ● male ▲ female controls)

An investigation was also made of 44 women with emphysema and a control group of 50 women considered clinically and radiologically to have normal lungs. The heart volumes were plotted against age (Fig 10 a). As with the men, most of the emphysema patients were in the lower part of the chart. The mean heart volumes and number of subjects in the different age groups appear in Fig 10 b. Again as with the males the heart volume was lower in the females with emphysema.

The diameters of the aorta were plotted for the different age groups of both sexes (Fig 11 a). The mean values indicated that the diameter of the aorta was larger in the emphysema patients than in the controls (Fig 11 b).

The cardio-aortic index for the women was plotted against age (Fig 12 a). The emphysema material lies in the lower part of the chart. The mean values of the index plotted against age groups (Fig 12 b) produced correlation between the emphysema women and the controls similar to that in the men. The indices for the male controls were approximately 250 and for the females 220 while those for emphysema had fallen to about 180 in the men and 160 in the women.

The correlations have all been based on pure radiologic observations and measurements. As an independent morphologic control of the lung changes was lacking comparison was supplied by some of the routine physiologic function

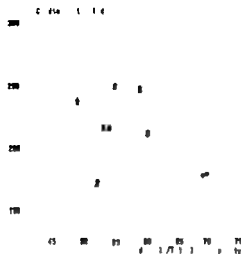


Fig 19

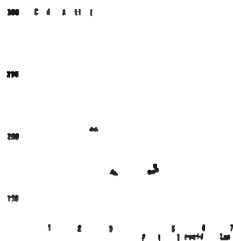


Fig 20

Fig 19 Correlation between the index and residual volume (l) to total lung capacity in 66 patients (O males Δ females with emphysema ● male ▲ female controls)

Fig 20 Correlation between the cardio-aortic index and functional residual volume (l) in 64 patients. The values for the functional residual volumes only just separate the patients with emphysema (O males Δ females) from the controls (● males ▲ females)

tests generally applied for a quantitative evaluation of pulmonary emphysema.

None of the function tests present in the records was excluded in the comparisons. Reports on different tests were however sometimes absent and may have explained the varying number of patients in the different comparisons.

The cardio-aortic index considered in relation to the inspiratory reserve volume in 27 of the emphysema males examined by the physiologic function tests produced relatively good direct correlation (Fig 13). A low index corresponds to low inspiratory reserve volume which in turn occurs in emphysema. The index plotted against the residual volumes produced clear differentiation of the two groups of patients (Fig 14). On the other hand residual volume determinations separated only some of the controls from the emphysema patients.

The relationship between cardio-aortic index and vital capacity also presented a certain degree of direct correlation (Fig 15). The correlation between the index and forced expiratory volume per second ($FEV_{1.0}$) was demonstrated in a combined material of men and women (Fig 16). The correlation between the index and the percentage of forced expiratory volume to total lung volume disclosed better separation of the emphysema patients from the controls (Fig 17) given by the physiologic function test or the index alone. The index compared to the maximum voluntary ventilation in 40 seconds (MVV_{40})

revealed remarkably good correlation (Fig 18) The index was considered in relation to the residual volumes to total lung capacity in Fig 19 It is believed that this ratio is one of the best function tests for the evaluation of the degree of emphysema (SWETT et coll 1960) The figures for this ratio in emphysema are situated to the lower right of the chart and those of the controls to the left The separation of the latter from the emphysema patients is, however, even better obtained by the index than by the function test

The index was also compared with the functional residual lung volume (Fig 20) The figure revealed good separation of the control from the emphysema material The functional residual volume parameter on the other hand, failed to disclose any obvious difference between the two groups

Discussion

The diminished heart volume in idiopathic pulmonary emphysema may be secondary to low physical workin., capacity A reduction in the retractive forces of the lung tissue will also produce a diminished inflow gradient for the blood into the thorax and decrease the respiratory effect on the diastolic filling of the heart The lowered capacity for gas exchange may also be an important factor in the relatively low physical activity of these patients Alterations in the cardiac volume of emphysema may consequently bear some correlation to its degree as the normal volume varies considerably it must be correlated to an appropriate parameter in each individual

The diameter of the aortic arch was chosen as a correlative parameter for the heart volume The main efferent tube of any pump should normally be of a dimension to carry the full output The diameter of the aorta probably matches the pumping capacity of the heart in normal biologic conditions A certain ratio should therefore exist between the volume of the normal heart and the size of the aorta this is supposed to vary to some extent in different age groups due to normal quality changes in the pump-tube system due to aging An absolute increase in diameter of the aorta occurred in the emphysema patients in all age groups A large aorta is not compatible with normal systemic blood pressure and reduced heart volume in the emphysema patients A change in the quality of the aortic wall is therefore likely to be present and gives rise to the question whether the alterations in quality in the pulmonary parenchyma and those anticipated in the aorta have a common denominator

It is of interest that the central bronchi and the central pulmonary arteries have presented no evidence of enlargement in the emphysema patients compared with the controls It is possible that some local degenerative changes may have been present in the lungs and the wall of the aorta in this material of idiopathic

emphysema. The absence of changes in calibre of the central pulmonary arteries may also have been against more general vascular involvement. A related factor for degeneration in the pulmonary parenchyma and the aortic wall that spares the central pulmonary arteries and bronchi, may be the function of the nutrient vessels of the affected organs, that is the bronchial arteries and the vasa vasorum of the aorta. Such a degenerative process due to insufficient bronchial arterial supply with preserved nutrition of the central bronchi and pulmonary arteries accords with the work of ISAAKSOHN (1871) LOPACHKE (1928) CUDKOWICZ & ARVSTRÖM (1953) DELARNE (1946) and FLORANOE (1960).

The bronchial arteries and the vasa vasorum of the aorta are all nutrient vessels of common origin. No investigation appears however so far to have been made about possible insufficiency of the vasa vasorum in idiopathic emphysema. Degeneration or atrophy due to insufficient systemic blood supply to the aortic wall and the pulmonary parenchyma seems, however to be a possible preliminary explanation for the alterations in these structures.

The absence of enlargement of the heart and the central pulmonary vessels in uncomplicated idiopathic emphysema seems to indicate that cor pulmonale and enlargement of the central pulmonary vessels are rarely present *in vivo* even in relatively advanced uncomplicated emphysema.

The cardio-aortic index and physiologic lung function tests have presented remarkably good correlation. This has been especially true between the index and the inspiratory reserve volume, the maximum voluntary ventilation the forced expiratory volume per second and the forced expiratory volume as a percentage of the total lung capacity. An even better separation of the controls from the emphysema patients was obtained by the index in comparing residual volume vital capacity residual volume/total lung capacity and functional residual volume.

When a qualitative diagnosis of diffuse uncomplicated emphysema can be made it seems possible to use the index as a guide for the quantitative estimation of the functional significance of the lung changes. The cardio-aortic index in complications such as cor pulmonale, general myocardial failure and pulmonary hypertension should however tend to move against the normal values due to enlargement of the heart.

Conclusions

A qualitative diagnosis of the idiopathic diffuse types of emphysema (centrilobular and panlobular) may usually be made by suitable radiologic examinations with films of high resolution. The heart in idiopathic emphysema

is usually small and the aorta wide the heart volume was calculated in 150 controls of different age groups and in 143 patients with emphysema. The diameter of the aortic arch as well as the left and right lower lobe bronchi and pulmonary artery were also measured. The heart volume was considerably smaller and the aortic diameter larger in patients with uncomplicated emphysema compared with the controls. The diameters of the central bronchi and pulmonary arteries were the same in the whole material. Evidence has earlier been presented that emphysema may be related to an insufficient bronchial arterial supply to the lung periphery but with the systemic arterial supply to the central bronchi and vessels preserved. The reason for the widening of the aorta is still obscure but may depend on a similar change in the nutrient vasa vasorum of the aortic wall: these are from the same source as the bronchial arteries. The decrease in heart volume may variously be correlated to the functional effect of the emphysema changes and has been discussed in detail.

The cardio-aortic index (heart volume/aortic diameter) enabled correlation to be made against different physiologic function tests. Remarkably good agreement was evident with the inspiratory reserve volume, the maximum voluntary ventilation and the forced expiratory volume. An even better separation of the controls from the emphysema patients was obtained by the index compared with the residual volume, vital capacity, residual volume/total lung capacity and functional residual volume. The index may perhaps become a practical guide in the quantitative estimation of the functional significance of the pulmonary abnormalities in uncomplicated diffuse emphysema.

SUMMARY

The size of the heart and of the aorta has been investigated in 143 patients with idiopathic emphysema. The cardio-aortic index is described and its value in the estimation of the correlation with the various tests of physiologic function discussed.

ZUSAMMENFASSUNG

Die Grösse des Herzens und der Aorta wurde bei 143 Patienten mit idiopathischem Emphysem untersucht. Der Herz-Aorten-Index wird beschrieben und dessen Wert bei der Bestimmung der Korrelation zu verschiedenen Tests der physiologischen Funktion diskutiert.

RÉSUMÉ

Les dimensions du cœur et de l'aorte ont été étudiées chez 143 malades atteints d'emphysème idiopathique. Les auteurs décrivent l'index cardio-aortique et examinent son intérêt dans l'estimation de la corrélation avec les divers tests de la fonction physiologique.

emphysema The absence of changes in calibre of the central pulmonary arteries may also have been against more general vascular involvement. A related factor for degeneration in the pulmonary parenchyma and the aortic wall that spares the central pulmonary arteries and bronchi may be the function of the nutrient vessels of the affected organs, that is the bronchial arteries and the vasa vasorum of the aorta. Such a degenerative process due to insufficient bronchial arterial supply with preserved nutrition of the central bronchi and pulmonary arteries accords with the work of ISAAKSOHN (1871) LOESCHKE (1928) CUDKOWICZ & ARMSTRONG (1953) DELARNE (1946) and FLORANCE (1960).

The bronchial arteries and the vasa vasorum of the aorta are all nutrient vessels of common origin. No investigation appears however so far to have been made about possible insufficiency of the vasa vasorum in idiopathic emphysema. Degeneration or atrophy due to insufficient systemic blood supply to the aortic wall and the pulmonary parenchyma seems however to be a possible preliminary explanation for the alterations in these structures.

The absence of enlargement of the heart and the central pulmonary vessels in uncomplicated idiopathic emphysema seems to indicate that *cor pulmonale* and enlargement of the central pulmonary vessels are rarely present *in vivo* even in relatively advanced uncomplicated emphysema.

The cardio-aortic index and physiologic lung function tests have presented remarkably good correlation. This has been especially true between the index and the inspiratory reserve volume, the maximum voluntary ventilation, the forced expiratory volume per second and the forced expiratory volume as a percentage of the total lung capacity. An even better separation of the controls from the emphysema patients was obtained by the index in comparing residual volume/vital capacity, residual volume/total lung capacity and functional residual volume.

Where a qualitative diagnosis of diffuse uncomplicated emphysema can be made it seems possible to use the index as a guide for the quantitative estimation of the functional significance of the lung changes. The cardio-aortic index in complications such as *cor pulmonale*, general myocardial failure and pulmonary hypertension, should however tend to move against the normal values due to enlargement of the heart.

Conclusions

A qualitative diagnosis of the idiopathic diffuse types of emphysema (centrilobular and panlobular) may usually be made by suitable radiologic examinations with films of high resolution. The heart in idiopathic emphysema

- JOHNSON B and SJÖSTRAND T. Circulatory data in normal subjects at rest and during exercise in recumbent position with special reference to the stroke volume at different work intensities. *Acta physiol scand* 49 (1960) 343
- LEHMANN I. Pathologisch-anatomische Veränderungen der Lungengefäße beim Emphysem. *Virchows Arch. path. Anat* 53 (1871) 466
- JORDAN S. A method for the determination of the heart size by teleroentgenography (a heart volume index). *Acta radiol* 20 (1939) 323
- LEFFORD J C and COLEMAN J. The centrilobular form of hypertrophic emphysema and its relation to chronic bronchitis. *Thorax* 16 (1971) 219
- and SMITH R. M. The broncho-vascular appearance of 'peripheral pooling' attributed to the filling of centrilobular emphysematous spaces. *Thorax* 16 (1961) 70
- LEIJSTRAND G, LYSEROLF E, NYLIN G and ZACHARISSON C. G. The normal heart volume in man. *Amer Heart J* 17 (1939) 406
- LOEWENHART H. Störungen des Luftgehaltes der Lunge. In: *Handbuch der speziellen pathologischen Anatomie und Histologie*. Band III S. 599. Herausgegeben von F. Henke und O. Lubarsch. Springer Verlag, Berlin 1928
- LYSEROLF E, NYLIN G and QUARLÅN K. The relation between the heart volume and stroke volume under physiological and pathological conditions. *Acta radiol* 15 (1934) 37
- MCLAUGHLIN H. H. The macroscopic anatomy of pulmonary emphysema. *Aust Ann Med* 5 (1956) 73
- The pathogenesis of pulmonary emphysema. *Amer J Med* 23 (1958) 62
- MURPHY G R, RIZZETTI JR A D, STEELE J D, WYATT J P and HARRIS II W. Chronic bronchitis, asthma and pulmonary emphysema. *Amer Rev resp Dis* 85 (1962) 762
- MORI P A, AXELSSON JR A E, ECKERT P. The radiological spectrum of aging and emphysematous lungs. *Radiology* 83 (1964) 48
- MOTLEY J P D. Emphysema heart disease. *Brit J Tuberc* 48 (1954) 63
- NYLIN G. Relation entre l'hypertrophie et le volume de sang résiduaire du cœur. *Acta radiol* 22 (1941) 736
- O LOUGHEED B J. Experimental approach to pulmonary emphysema. *Amer J Roentgenol* 93 (1965) 830
- OUTERIDGE K G, McLAUGHLIN I and WHITE A. H. Some findings on the post mortem association of right ventricular wall thickness and chronic obstructive bronchitis, pneumococcal emphysema and tuberculosis. *Med J Aust* 2 (1970) 930
- PARKER R L. Pulmonary emphysema. A study of its relation to the heart and pulmonary arterial system. *Ann intern Med* 14 (1940) 793
- PRIOR J A and EBBERT R. V. The elastic properties of the lungs in the aged. *J Lab clin Med* 31 (1956) 63
- HOCUTT J B and EBBERT R. V. Studies of lung collagen and elastin. Part II. *Amer Rev resp Dis* 80 (1959) 45
- — — The collagen and elastin content of the lung in emphysema. *Ann intern Med* 55 (1961) 210
- RAND L. *Advances in internal medicine*. Edited by W. Dock and I. Snapper. Year Book Medical Publishers Inc. Chicago 1964
- PATRICK M C and MILLARD F J C. Correlation between radiological diagnosis and structural lung changes in emphysema. *Clin Radiol* 15 (1960) 307
- SIMON C. Radiology and emphysema. *Clin Radiol* 15 (1964) 293
- STRAUD W W, FRY D L and EBBERT R. V. The elastic properties of the lung in normal men and in patients with chronic pulmonary emphysema. *J Lab clin Med* 40 (1952) 674

- SWEET H C, WYATT J P and KIDWELL P W Correlation of lung macrosections with pulmonary function in emphysema *Amer J Med* 29 (1960) 277
- TITURLESCA W M Internal surface area and other measurements in emphysema *Thorax* 22 (1967) 483
- WYATT J P, FISCHER V W and SWEET H C Panlobular emphysema: Anatomy and pathodynamics *Dis Chest* 41 (1962) 239
- — — (a) The pathomorphology of the emphysema complex Part I *Amer Rev resp Dis* 89 (1964) 533
- — — (b) The pathomorphology of the emphysema complex Part II *Amer Rev resp Dis* 89 (1964) 721
- WEINEL E R Morphometrische Analyse von Zahl, Volumen und Oberfläche der Alveolen und Kapillaren der menschlichen Lunge *Z Zellforsch* 57 (1962) 648

FROM THE DIVISION OF PHARMACOLOGY (DIRECTOR PROF P LINDÖREN) DEPARTMENT OF DRUGS NATIONAL BOARD OF HEALTH AND WELFARE 104 01 STOCKHOLM AND THE DEPARTMENTS OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF E F SALTZMAN) AND SURGERY (DIRECTOR PROF E NOROSTRÖM) UMEÅ UNIVERSITY 901 85 UMEÅ SWEDEN

INTRAVENOUS CHOLEGRAPHY AND PERORAL CONTRACEPTIVES

A preliminary report

P LINDÖREN G F SALTZMAN and E ZEUCHNER

The clinical trials with parenterally administered contrast media that have been in progress for some years at the department of diagnostic radiology at the teaching hospital in Umeå have necessitated the routine recording of all side effects. During the same period the surgical department has been investigating the side effects resulting from oral contraceptives (PHEL et coll 1968). A considerable number of side effects have been observed when Bilvistan was used as contrast medium for cholegraphy in young women taking contraceptives suggesting that there might be a relation between these compounds. These observations prompted us to analyse the free and ex distribution in a series of 500 consecutive intravenous cholegrams and to carry out circulation examinations in animals to gain further information.

Communicated at the 28th C
Sweden 14-17 June 1967. Sul

at Scandinavian Radiological Society in Umeå
publication 2 April 1973

Table

Clinical and radiologic findings (For details concerning the examination of the biopsy material with light and electron microscopes see PHEL et coll. 1968)

Case	Bili- rubin mg	Thymol line phos- phatase	Alka- line phos- phatase	GOT	GPT	LDH	HBD	Sulfo- bromo- phtha- lein	Liver biopsy	Cholegraphy	
										Con- trast filling of bile ducts	Side effects
1	0.8	0.4	11.2	87	34	340	28.5	—	Pathol.	+	—
2	0.9	0.2	8.3	98	160	245	170	—	Pathol.	0	—
3	0.8	—	9.4	110	130	250	170	5.3	Pathol.	0	—
4	1.3	2.3	11.0	49	52	380	240	—	Pathol.	0	—
	0.4	0.6	—	28	32	21.5	140	5.0	Pathol.	+	—
6	0.4	—	—	46	66	100	250	4.1	Possibly pathol.	+	—
7	0.6	1.0	4.9	18	16	—	—	6.2	Not done	+	—
8	0.3	1.2	7.7	26	23	150	140	—	Not done	0	—
9	0	—	—	22	23	180	130	—	Not done	—	—
10	1.1	0	2.7	30	31	260	230	12.9	Not done	+	—
11	0.6	0.4	3.3	—	—	—	—	—	Not done	+	—

Material Intravenous cholegraphy was performed in 11 women who had been taking Anovlar (Schering) Conluton (Astra) or Lyndiol mite (Pharmacia) for a long period. The dominant substance in all these contraceptives is a progesterone derivative with small amounts of oestrogen added. The cholegraphy was carried out because of uncharacteristic abdominal pain; the contrast medium used being ioglicamide (Bilvistan) which gives less side reactions than other available contrast media (BRISMAN et coll. 1971 and others). The serum bilirubin concentration was recorded for all the women, and in most of them a thymol turbidity test as well as tests for alkaline phosphatase and transaminase (GOT, GPT, LDH and HBD) were also performed. Sulfobromophthalein loading was carried out in 5 instances. In 6 women, liver biopsy was done, the material obtained being examined in both light and electron microscopes.

In view of the observations in these 11 cases, the side effects in a series of 500 consecutive intravenous cholegraphies were analysed with respect to the age and sex distribution. This material has been described by BRISMAN et coll. in another context, but hormonal aspects were not taken into consideration in their report.

Since progesterone is the dominant component in all contraceptives, we pre-treated a few cats with large doses of progesterone intramuscularly (Progestin

Pharmacia) and the following day administered Bilvistan intravenously and Biligrafin forte in an amount corresponding to a large clinical dose. The systemic blood pressure was measured in the left common carotid artery and the pressure in the right ventricle through a fine plastic catheter introduced into the heart via the right jugular vein. The recordings were made with electromanometers (Statham P 23AA) connected to a Grass model 5 polygraph, as described in more detail in a previous paper (LUNDQVIST *et coll.* 1964).

Results

Clinical investigation The findings in the 11 cases are given in the Table.

Two remarkable observations were made in connection with the cholegraphies in these patients. First, there were 4 cases in which despite normal serum bilirubin concentrations no contrast filling of the bile ducts was obtained. Although the present material is small, this frequency is undoubtedly surprising, considering that BRISMAR *et coll.* among 500 cholegraphies, had only 4 unexplainable cases of defective bile duct filling in conjunction with normal bilirubin values. Secondly there was a high incidence of side effects. Five patients had nausea and vomiting, in other words the most troublesome and unpleasant reactions (apart from a case of circulatory collapse reported by BRISMAR *et coll.*) noted by us in connection with the use of Bilvistan as a contrast medium: none of these patients had had similar symptoms before the roentgen examination. Compared with the incidence of established side effects from Bilvistan (9.8 per cent) reported by BRISMAR *et coll.* the present frequency seems to be high.

There would seem to be some correlation between demonstrable liver injury on the one hand and frequency of side reactions and incomplete filling of the bile ducts on the other. That histologically demonstrable liver injury and defective duct filling would be parallel phenomena is hardly surprising, but the high frequency of side effects is noteworthy on the other hand, seeing that it has never been possible, in icterus, to record definite side reactions due to the contrast medium (TILANDER 1955; BRISMAR *et coll.*)

The progesterone content in the blood is highest in women of fertile age but it varies considerably from phase to phase in the menstrual cycle. It has not previously been possible to survey side effect rate in relation to menstrual cycle phase: the age and sex distribution in a series of 500 consecutive cholegraphies reveals however that there are noticeable differences with respect to the side effect rate between women of fertile and non fertile ages. Like BRISMAR *et coll.* we recorded separately those symptoms which had not been noted before the examination (unmistakable side effect) and such symptoms as had already been present in the same degree before the cholegraphy. Of 142 women of fertile age

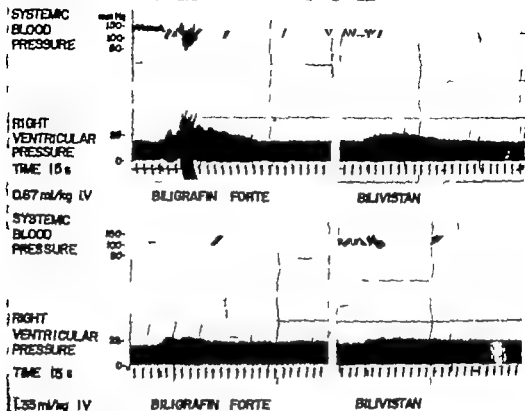


Fig. 1. Cat 3.0 kg pretreated (24 h) with progesterone 15 mg/kg intramuscularly. C: ul-
tury effects of Biligrafin forte (30%) and Bilivistan (30%) given as rapid intravenous in-
jections.

20 (14.1 per cent) had unmistakable side effects and 13 (9.2 per cent) the same symptoms as before examination of 209 women of non fertile age 14 (6.7 per cent) had unmistakable side effects and 18 (8.6 per cent) the same symptoms as before examination.

All these clinical observations suggest that there is a relation between female sex hormones and the contrast medium used at intravenous cholangiography. This applies particularly to the incidence of side effects at cholangiography. The material is still small, however.

Experimental investigation. In view of the great preponderance of progesterone in all the oral contraceptives in use at present, a few cats were pretreated as a preliminary step with 15 mg/kg Progestin intramuscularly and 24



Fig 2 Cat 2.6 kg pretreated (24 h) with progesterone 15 mg/kg intramuscularly. Effects on systemic blood pressure and right ventricular pressure of Bilivistan and Biligrafin forte given as rapid intravenous injections.

hours later were given a rapid injection of contrast medium, Biligrafin forte or Bilivistan.

One characteristic experiment is illustrated in Fig 1. An amount of 0.67 ml/kg Biligrafin forte was administered intravenously and the result was a slightly deeper fall in blood pressure than has generally been observed in untreated animals in earlier experiments (LINDGREN & SALTZMAN 1962). A marked rise in the systolic pressure in the right ventricle occurred at the same time. These pressure rises tended to be wave shaped, reaching when greatest to approximately twice the initial level. After 35 seconds, the cat had a bad vomiting attack which lasted for a further half a minute and could be distinctly observed in the marked oscillations in both blood pressure and ventricular pressure curves. The blood pressure and ventricular pressure reactions subsided after a further 3 to 4 minutes. A subsequent injection of Bilivistan in the same dose produced a similar reaction though with quantitatively smaller tracings and without the vomiting. The two injections were repeated approximately one hour later with the dose doubled. The fall in the blood pressure and above all the pressure rise in the right ventricle, were now much less marked, suggesting that tachyphylaxis had developed. Tachyphylaxis of this type also occurs in cats not treated with progesterone (LINDGREN & SALTZMAN).

The phenomenon makes it difficult to draw conclusions from the experiment with respect to a comparison between the two contrast media. It would in fact be reasonable to expect a certain degree of, or possibly even a full, considerable cross-tachyphylaxis.

For this reason, Bilivstan was given as the first preparation in the second experiment (Fig. 2). The fall in blood pressure was slightly smaller than when Biligrafin was given first, but on the other hand the cat had a relatively low initial blood pressure level. The pressure rise in the right ventricle was however of the same order of magnitude as it had been for Biligrafin. The rise took place in waves in this experiment also, and subsided after 3 to 4 minutes. A subsequent injection of Biligrafin in the same dose produced a relatively small reaction, suggesting that cross tachyphylaxis had developed.

Discussion

Although our clinical and experimental series were both small, the observations already made suggest that unfavourable effects may arise in a situation in which ioglycamide (Bilivstan) is given to women with high sex hormone activity. The consequences in practice, would seem to be a higher rate of side effects in women of fertile age than in women of non fertile age as well as a high rate of side reactions in women who have been on oral contraceptives for a long period and a risk of unsatisfactory contrast filling of the bile ducts in the latter women. At the 28th Congress of the Scandinavian Radiological Society where these observations were reported for the first time, WILBRAND in the subsequent discussion, described similar cases with side reactions at cholangiography in women taking oral contraceptives over long periods. In his material also the frequency of the reactions was much higher in women of fertile age than in other patient groups.

These clinical observations were complemented by the findings in animal experiments, namely that definitely increased circulatory ioglycamide effects could be observed in cats pretreated with progesterone. It should be stressed that the dose of progesterone was very large: the object was merely to obtain qualitative information as to whether such a form of pretreatment would in general have any effect on the circulatory side reactions to bile duct contrast media. The fall in the blood pressure after an intravenous injection of iodipamide or ioglycamide thus seemed larger than in cats not pretreated with these preparations (BRISMAR *et coll.*). The pressure increase in the right ventricle was remarkable. In an earlier paper (LINDORÉN *et coll.*) the rise in the systolic right ventricular pressure was given as 10 to 16 per cent over the initial level. Bilivstan, in similar experiments, has produced slightly smaller reactions (BRISMAR *et coll.*). This level was considerably exceeded in the progesterone treated animals, increases reaching at most 100 per cent being observed for both Biligrafin and Bilivstan.

As regards the increases in the right ventricular pressure marked tachyphylaxis was observed when only one contrast medium was used, and a considerable degree when iodipamide and ioglycamide were given alternately. The

cats displayed a strong tendency to vomit similar to that observed in the women.

The smallness of the material does not permit conclusions to be drawn regarding the mechanism underlying the effects obtained. Increased pressure in the right ventricle has been observed in connection with intravenous administration of several different contrast media and this effect has been placed in relation to increased intravascular erythrocyte aggregation (for references, see LINDGREN *et coll.*). This tendency to aggregation might conceivably be heightened in connection with peroral contraception. Support for this hypothesis has been contributed by LAURELL *et coll.* who after peroral contraception, observed displacements in the relation between the serum proteins that could well have served as a predisposing factor in producing increased intravascular erythrocyte aggregation.

Acknowledgement

The investigation was supported by the Swedish Medical Research Council Grant No B 67 14 207701.

SUMMARY

A preliminary report is given on the side effects observed at intravenous cholegraphy with iodipamid in women who had been taking oral contraceptives over a long period. The age and sex distribution for side effects in a large series of cholegraphs is discussed. The circulatory effects on administration of ioglycamid and iodipamid to cats pretreated with progesterone were also investigated.

ZUSAMMENFASSUNG

Es wird ein vorläufiger Bericht über Nebenwirkungen bei der intravenösen Cholegraphie mit Iodipamid bei Frauen, die lange Zeit orale Antikontrazeptivumittel angewendet hatten, gegeben. Das Alter und die Geschlechtsverteilung für Nebeneffekte in grossen Serien von Cholegraphien werden diskutiert. Der Zirkulationseffekt nach Gabe von Ioglycamid und Iodipamid bei Katzen, die mit Progesteron behandelt waren, wurde ebenfalls untersucht.

RÉSUMÉ

Les auteurs font une étude préliminaire des effets secondaires observés dans la cholegraphie intraveineuse par l'iodipamide chez des femmes qui avaient pris pendant une longue période des contraceptifs par voie orale. Ils examinent sur de grandes séries de cholegraphies la distribution des effets secondaires en fonction de l'âge et du sexe. Ils ont aussi étudié les effets circulatoires de l'administration d'ioglycamide et d'iodipamide des chats traités préalablement par la progesterone.

REFERENCES

- BRINMAR, J., LINDGREN, P. and SALTZMAN, G. F. Ioglycamide (Bilvistan) as contrast medium for intravenous cholangiography. A clinical and experimental investigation. *Acta radiol. Diagnosis* 11 (1971) 129.
- GOLDSCHMIDT, H. and LINDGREN, P. An electronic interval recorder for measuring blood flow and heart rate. *J. appl. Physiol.* 17 (1962) 169.
- LAURELL, C. B., ALLANDER, S. and THORSELL, J. Effect of administration of a combined estrogen-progestin contraceptive on the level of individual plasma proteins. *Scand. J. clin. Lab. Invest.* 21 (1968) 337.
- LINDGREN, P. and SALTZMAN, G. F. Effects of intravenous administration of urographic and cholangiographic contrast media on blood pressure and peripheral circulation. An experimental study in cats. *Acta radiol.* 57 (1962) 341.
- , LÖFSTRÖM, B. and SALTZMAN, G. F. Intravascular erythrocyte aggregation after intravenous injection of contrast media. *Acta radiol. Diagnosis* 2 (1964) 354.
- PIHL, E., RAN, O. and ZEUCHNER, E. Functional and morphological liver changes in women taking oral contraceptives. *Acta chir. scand.* 134 (1968) 639.
- TRELANDER, G. Side-effects of Biligrafin. *Acta radiol.* 43 (1955) 369.
- WILBRAND, H. F. Discussion at the 28th Congress of the Scandinavian Radiological Society. Umeå 1967.

CARCINOMA OF THE GALLBLADDER

A review of 158 cases

H. PETTERSSON

Primary carcinoma of the gallbladder is uncommon. The early stages are nearly always asymptomatic and if symptoms do occur they are nearly always secondary to co-existing cholecystitis or cholelithiasis. More severe symptoms do not appear until the disease is well advanced and has spread beyond the gall bladder; these include obstructive jaundice, right upper quadrant pain, anorexia, weight loss, and fatigue. Palpation in this phase often discloses a mass in the right upper quadrant and occasionally an enlarged liver. Some patients fail to seek medical help until they are in an even further advanced stage, with ileus, ascites or diffuse gastrointestinal bleeding.

An early diagnosis is difficult but necessary if the prognosis is not to be hopeless. The application of roentgenology in the diagnosis of this disease has until now been limited. The results will be described and the value of the radiologic procedures that have been performed in patients with confirmed carcinoma of the gallbladder will be discussed.

Material: A total of 181 cases of primary malignancy of the gallbladder were collected during the 15 year period 1957 and 1971. This material was previously

Submitted for publication 1 February 1973

REFERENCES

- RADMAR, J., LINDQREN, P. and SALTZMAN, G. F. Ioglycanate (Bilvistan) as contrast medium for intravenous cholangiography. A clinical and experimental investigation. *Acta radiol Diagnost* 11 (1971) 129.
- GOLDSTEIN, H. and LINDQREN, P. An electronic interval recorder for measuring blood flow and heart rate. *J appl Physiol* 17 (1962) 169.
- LAURELL, C. B., HULLANDER, G. and THORELL, J. Effect of administration of a combined estrogen-progestin contraceptive on the level of individual plasma proteins. *Scand J clin Lab Invest* 21 (1968) 337.
- LINDQREN, P. and SALTZMAN, G. F. Effects of intravenous administration of urographic and cholangiographic contrast media on blood pressure and peripheral circulation. An experimental study in cats. *Acta radiol* 57 (1962) 341.
- , LOPFROW, B. and SALTZMAN, G. F. Intravascular erythrocyte aggregation after intravenous injection of contrast media. *Acta radiol Diagnost* 2 (1964) 334.
- PHIL, E., RAN, O. and ZEUCHNER, E. Functional and morphological liver changes in women taking oral contraceptives. *Acta chir scand* 134 (1968) 639.
- THELANDER, G. Side effects of Biligrafin. *Acta radiol* 45 (1955) 369.
- WILBRAND, H. F. Discussion at the 28th Congress of the Scandinavian Radiological Society. Umeå 1967.



Fig 1 Cholecystography with demonstrable tumour. Circumscribed rigid deformity of the wall of fundus of gallbladder (Microscopy: adenocarcinoma). P a) b) Obliqu

b

Depending on the questions they underwent cholecystography, intravenous cholangiography, percutaneous transhepatic cholangiography, survey films of the abdomen, contrast examinations of the gastrointestinal tract and angiography (3 cases).

The clinical appearances led to laparotomy in 116 cases, after which the diagnosis could be verified microscopically; in the other cases the diagnosis was not established before autopsy.

The material was divided into three groups depending on when the radiologic examination was performed in relation to the verification: those in which the examinations were accomplished less than six months before the microscopic diagnosis, those in which the interval was between 6 and 12 months, and those in which more than 12 months elapsed.

Results

Inadequate or no concentration of contrast medium in the gallbladder was the usual finding at cholecystography (Table 1) and in no case was the gallbladder normal. Adequate concentration was evident in two cases with a filling defect that at operation appeared to be caused by carcinoma (Figs 1, 2). Four cases of so-called porcelain gallbladder (calcification of the gallbladder wall) were noted (Fig 3).

Operative cholangiography was performed in 26 cases, 7 of which had



Fig 2



Fig 3

Fig 2 Cholecystography with demonstrable tumour. A segment of the neck of the gallbladder was deformed (\rightarrow). Operation 5 months later the region was thickened secondary adenocarcinoma.

Fig 3 Porcelain gallbladder with malignant infiltration. Cholecystography revealed non-filling gallbladder. Histology calcification of the wall of the gallbladder which was totally overgrown by a low differentiated adenocarcinoma.

narrowing of the common bile duct by a tumour and in one case narrowing of the cystic duct. Obliteration of a hepatic duct was observed in another case. This at autopsy was seen to be caused by a hepatic metastasis. It never appeared that the changes were caused by a tumour arising in the gallbladder.

Postoperative cholangiography was performed in 16 cases. Malignant obliteration of the hepatic and common ducts was evident in 6 cases, all but one observed earlier at the operative examination. Infiltration of the cystic duct was present in one case (Fig 4).

Percutaneous transhepatic cholangiography was performed in 2 cases, in both of these marked changes were observed with obliteration of the hepatic ducts although it was not possible to localize the primary lesion.

Cholegraphy including tomography performed in 8 cases failed to reveal a carcinoma of the gallbladder.



Fig 4 Adenocarcinoma of gallbladder removed by cholecystectomy and partial resection of the liver. The proximal part of the cystic duct was unusable. Postoperative cholangiography disclosed that the contrast medium was leaking through an infiltrated cystic duct (→)

Survey films of the abdomen disclosed a mass in the right upper quadrant in 3 cases (Table 2). No specific evidence existed that the tumour arose from the gallbladder but on the other hand the appearances were not those simply of an enlarged liver. Hepatomegaly was usually caused by metastases from carcinoma of the gallbladder. Splenomegaly in one case was based on cirrhosis of the liver in the other the enlargement of the spleen was probably due to pressure from the tumour on the porta hepatis. Dilatation of the stomach stems or ascites some times occurred in advanced cases with extensive carcinomatous of the peritoneum.

The upper gastrointestinal examination disclosed extrinsic pressure and invasion cranially of the bulb and superior part of the duodenum as the most common relevant positive finding (Table 3 Fig 5). Extrinsic pressure and infiltration superiorly on the pylorus and antrum were observed in 5 cases and were due to the presence of a mass in the region of the cystic and common bile ducts in 4 others a change in the duodenum could not be differentiated from a tumour in the head of the pancreas the carcinoma of the gallbladder in these cases had spread to the pancreas. Malignant invasion in 7 cases led to gastric retention

Table 2

Findings on survey films of the abdomen

	Time between examination and macroscopy		
	Under 6 months	6-12 months	Over 12 months
Total number of examinations	60	3	4
Normal	17	3	4
Mass in right upper quadrant	3		
Hepatomegaly	14		
Splenomegaly	2		
Gastric dilatation	4		
Neus	5		
Meteor	7		
Gallbladder calculi	11		

The other cases of retention (Table 3) had no direct connection with the carcinoma of the gallbladder. One patient had a fistula between the duodenum and tumour of the gallbladder (Fig. 6).

Barium examination of the small bowel was performed in 12 cases; one had

Table 3

Findings at upper gastrointestinal examination

	Time between examination and macroscopy		
	Under 6 months	6-12 months	Over 12 months
Total number of examinations	93	12	30
Normal	46	9	37
Extrinsic pressure and invasion of bulb and superior part of duodenum	11	0	0
Extrinsic pressure and invasion of antrum and pylorus	3	0	0
Duodenal infiltration and displacement simulating tumour of head of pancreas	4	0	0
Gastric retention	7	1	3
Fistula between duodenum and tumour	1	0	0
Duodenal ulcer post ulcerative deformity	7	1	
Gastric ulcer or neoplasia	2	1	2
Small changes without relation to carcinoma of the gallbladder	18	1	8



Fig 5



Fig 6

Fig 5 Adenocarcinoma of the gallbladder infiltrating the bulb the superior part of the duodenum and the antrum

Fig 6 Barium meal. Fistula between the duodenum and gallbladder with carcinoma

gastric dilatation and 2 cases had ileus. Another case had constriction of the transverse colon. The colon was examined by the double contrast technique in 53 cases. 31 of these examinations were performed within half a year of the histologic diagnosis and 5 had infiltration of the superior wall of the transverse colon (Fig 7). No changes relevant to the diagnosis of carcinoma of the gallbladder were evident in the remaining 22 examinations performed over 6 months before the histologic diagnosis.

Two cases included here were subjected to celiac angiography shortly before operation and led to the correct preoperative diagnosis: the cystic artery was enlarged, its wall infiltrated and had cut-off branches and neovascularization existed (Fig 8). Another case examined more than a year before operation had normal gallbladder arteries.

Discussion

Most roentgenologic methods have proved to be insufficient for the diagnosis of early carcinoma of the gallbladder. The present investigation has revealed that almost all relevant positive findings were made only within half a year before the histologic diagnosis, i.e. in an advanced phase of the disease.

Cholecystography would be of value if it were possible to obtain adequate concentration of the contrast medium. However, inadequate or no filling with or



Fig 7

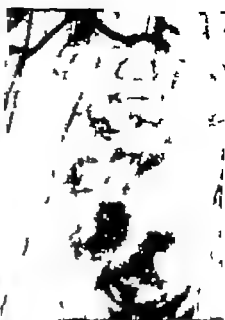


Fig 8

Fig 7 Adenocarcinoma of the gallbladder infiltrating the transverse colon (→) Metastases to the peritoneum have caused constriction of the colon both in the sigmoid and the hepatic flexure

Fig 8 Angiography with simultaneous injection into the celiac and superior mesenteric arteries. The cystic artery is stenosed and infiltrated (→) Infiltration and neovascularity evident along the anterolateral branch of the cystic artery (↔)

without calculi are commonly reported in the literature and is explained by the fact that most malignancies of the gallbladder are combined with cholecystitis or cholelithiasis. Reports of adequate concentration with a filling defect due to carcinoma are rare: only 8 cases having been described during the last 40 years (BUCKSTEIN 1953, CIMINO 1958, FELDMAN 1957, SCHINZ et al. 1965, TABARI & McNEER 1963, TATERA 1931). The two cases described here illustrate that satisfactory filling of the gallbladder does not exclude malignancy of the wall and that the tumour may in fact be observed.

The four cases of porcelain gallbladder demand closer attention. Case reports of porcelain gallbladder combined with carcinoma, have been published several times (BROWN 1932, BUCKSTEIN 1953, CORNELL & CLARKE 1959, LANGE 1955, OCHSNER & CARRERA 1963, POLA 1966, ZAWADOWSKI & PLEWIAK 1936). ETALA (1967) reported 16 cases. About 100 cases of porcelain gallbladder have been described, among which 22 have been malignant (POLA). During the

5 year period 1967—1971 17 256 cholecystographies performed at our hospital included 11 cases of porcelain gallbladder. Only one of these was operated upon and appeared to be benign. A total of 48 377 cholecystographies have been performed during the 15 year period of this investigation. Thus about 22 cases of porcelain gallbladder should have been encountered with 4 of these malignant. The coincidence of porcelain gallbladder and carcinoma of the gallbladder is consequently high. The demonstration of a porcelain gallbladder should therefore in itself be an indication for cholecystectomy.

It is remarkable that cholecystography was performed more than one year before the pathologic diagnosis in only 36 cases. This may be a good indication as to how difficult it is to interpret the signs of early phases of the disease. It is of interest also that of these early investigations not one was normal.

It was possible as previously stated to observe the tumour at cholecystography when adequate contrast filling of the gallbladder was obtained. Infusion cholangiography enables the gallbladder to be demonstrated through passive filling. Thus, if this examination were always performed when cholecystography failed in giving adequate contrast concentration some further tumours might be revealed. This indication for infusion cholangiography could be one approach to the earlier diagnosis of carcinoma of the gallbladder.

Operative and postoperative cholangiography made it possible to demonstrate carcinoma of the gallbladder when spread was present beyond the gallbladder to the ducts. Owing to the technique of these examinations the early primary tumour was never demonstrated. The literature indicates that the diagnosis of carcinoma of the gallbladder has been made at percutaneous transhepatic cholangiography (BAYENDE 1968; McNEILLY 1967). However with this method more information is gained if it be combined with angiography (BAYENDE, BORJSEN & REUTER 1967). BORJSEN & REUTER thus reported a case of obstructive jaundice in which a combination of percutaneous transhepatic cholangiography and celacography demonstrated carcinoma of the gallbladder with metastases to the hilum of the liver.

Survey film of the abdomen failed to afford good guidance as to the diagnosis. A local collection of gas in a mass situated at the site of the gallbladder has been regarded as almost pathognomonic by certain writers (ARMSTRONG 1949; MCCORVEL 1957). No such case was noted in the present series and the other positive findings were not characteristic.

Upper gastrointestinal examination has been described as the routine method to afford most information regarding the diagnosis of carcinoma of the gallbladder (MCCORVEL 1957; JAHLEMAN *et coll.* 1962; LYST KRISTENSEN *et coll.* 1971; HELICZ 1970). This was also the impression in the present investigation. Extrinsic pressure and invasion of the antrum, the pylorus or the bulb or superior

part of the duodenum gave a distinct indication of malignancy in the region of the gallbladder. It was however impossible to determine whether a growth really lay in the wall of the gallbladder. The carcinoma had always extended outside the gallbladder and the cases were beyond effective therapy.

Investigation of the colon with the double contrast technique failed to produce more information than the ordinary colonic enema. The same changes as described here have been reported earlier with the latter technique (LANGE 1955, KAIST, KRISTENSEN et coll. 1971).

Among all methods that were evaluated angiography of the abdominal vessels appeared to be the most reliable. This was in accordance with previous investigations, which have indicated either or selective hepatic angiography to be a safe means of demonstrating malignancy of the gallbladder (ABRAMS et coll. 1970, BOLJAK & RUTTER 1967, DRUSCH 1967, RUTTER et coll. 1971, ROSECRUICK et coll. 1969, SIEGALOFF & MESSING 1972, WENZ 1967). All published reports have included some of the following criteria of carcinoma of the gallbladder: enlarged hepatic or cystic artery, infiltration and cut off of the cystic artery or its branches and neovasculation of the cystic wall. ABRAMS et coll. also described irregular thickening of the gallbladder wall recognizable in the venous phase, which was regarded as an important criterion in the diagnosis of carcinoma of the gallbladder. This was not observed in the present material nor in the 2 further cases examined later in 1972.

Angiography should disclose carcinoma of the gallbladder earlier when the disease is still localized to the wall. However, as in pancreatic carcinoma, the problem is that the patient comes too late for diagnosis owing to the fact that the symptoms in the early phase of the disease are so non-specific. The therapeutic possibilities available today afford only the carcinoma in situ a good prognosis (OHLSSON & ARONSON 1973). The tumour in the early phase is not demonstrable with any radiologic method.

SUMMARY

A total of 158 patients with carcinoma of the gallbladder were investigated with various radiologic methods during a 15 year period. Almost all relevant positive findings were made in the late phase of the disease when the growth had already spread. A high incidence of porcelain gallbladder and carcinoma of the gallbladder was demonstrated and the presence of a porcelain gallbladder was suggested as indication for cholecystectomy. Upper gastrointestinal examination gave most information among the routine methods but angiography of the celiac and superior mesenteric arteries appeared to produce even more reliable information and should perhaps make a relatively early diagnosis possible.

ZUSAMMENFASSUNG

Insgesamt 158 Patienten mit malignem Karzinom der Gallenblase wurden während einer 15-Jahresperiode mit verschiedenen roentgenologischen Methoden untersucht. Fast alle

relevanten positiven Befunde wurden in einer späten Phase der Erkrankung erhoben wenn auch das Wachstum bereits ausgebreitet hat. Es wird ein häufigeres Vorkommen einer Porzellangallenblase und einem Krebs der Gallenblase nachgewiesen und das Vorkommen einer Porzellangallenblase wird als Indikation für eine Cholezystektomie angesehen. Die obere gastrointestinale Untersuchung ergab unter den Routine Methoden die best Information jedoch scheint die Angiographie der A. coeliaca und der A. mesenterica superior noch bessere Information zu geben und sollte eine relativ frühzeitige Diagnose ermöglichen.

RÉSUMÉ

Un total de 158 malades atteints d'un cancer de la vésicule biliaire ont été examinés par différentes méthodes radiologiques au cours d'une période de 15 ans. Presque tous les signes radiologiques positifs ont été constatés à une phase tardive de la maladie quand la tumeur était déjà disséminée. L'auteur a prouvé une haute fréquence de vésicule porcelaine et de cancer de la vésicule il pense que la présence d'une vésicule porcelaine est une indication de cholecystectomie. Parmi les méthodes courantes c'est l'examen gastro-intestinal par voie haute qui donne le plus de renseignements mais l'angiographie des artères coeliaque et mésentérique supérieure paraît donner des renseignements encore plus fidèles et devrait peut être permettre un diagnostic relativement précoce.

REFERENCES

- ABRAMS R. M., MENDO C. H., FINKELSTEIN H., BERENBAUM E. R. and ELLIOTT H. V. Angiographic demonstration of carcinoma of the gallbladder. *Radiology* 94 (1970) 277.
- ARMSTRONG T. C. Primary carcinoma of the gallbladder. *Cancer* 2 (1949) 579.
- BARTON R. S. Der Wert der kombinierten perkutanen transhepatischen Cholangiographie und Zolangiographie bei der Diagnostik des tumorbedingten Verschlussikterus. *Fortschr. Röntgenstr.* 109 (1968) 16.
- BORSEV E. and REUTER S. R. Combined percutaneous transhepatic cholangiography and angiography in the evaluation of obstructive jaundice. *Amer. J. Roentgenol.* 99 (1967) 153.
- BROWN R. Calcification of the gallbladder. *West. J. Surg.* 40 (1932) 70.
- BLOCHMANN J. The digestive tract in roentgenology. Second edition, pp 986-1018. J. B. Lippincott and Co. Philadelphia 1953.
- CINERMA C. V. Carcinoma in a well functioning gallbladder. *Roentgenological diagnosis. Radiology* 71 (1958) 563.
- CORRELL C. and CLARKE R. Vicarious calcification involving the gallbladder. *Ann. Surg.* 149 (1959) 267.
- DEUTSCH V. Cholecysto-angiography: visualization of gallbladder by selective coeliac and mesenteric angiography. *Amer. J. Roentgenol.* 101 (1967) 608.
- EL ALA E. Cancer de la vésicule biliaire. (In Spanish). *Pres. méd. argent.* 49 (1962) 2283.
- FELDMAN M. Clinical roentgenology of the digestive tract. Fourth edition. Williams & Wilkins Co. Baltimore 1937.
- ELBERT H. H. Primary carcinoma of the gallbladder. A thirty year summary. *Ann. Surg.* 153 (1961) 369.
- GERARD M. Cancer de la vésicule biliaire. Considérations actuelles. *Rev. int. Hépat.* 19 (1969) 571.

- KHILMAN M T, WOLF B S and FINKEL M Roentgen features of carcinoma of the gallbladder on barium meal examination *Radiology* 79 (1962) 264
- KULICZ A Ocena wartosci rutynowego badania radiologicznego zoladka i dwunastnicy w rozpoznawaniu raka pecherzyka zolcowego (The value of routine radiologic examination of the stomach and duodenum in the diagnosis of gall bladder cancer) (In Polish) *Pol Przegl radiol* 34 (1970) 817
- KITTEL K, KRISTENSEN J, KJOLLER E og BOJSEN MOLLER J Cancer ved en fellec Et materielle (In Danish) *Ugeskr Læg* 133 (1971) 1157
- LANO L Porzellangallenblase und Gallenblasenkarzinom *Fortschr Röntgenstr* 82 (1955) 411
- LITWIN M ■ Primary carcinoma of the gallbladder *Arch Surg* 95 (1967) 236
- McCONNEL F Malignant neoplasm of the gallbladder Roentgenological diagnosis *Radiology* 69 (1957) 720
- McNULTY J G Preoperative diagnosis of carcinoma of the gallbladder by percutaneous transhepatic cholangiography *Amer J Roengenol* 101 (1967) 605
- OCIBYER S F and CARRERA G M Calcification of the gallbladder (porcelain gallbladder) *Amer J Roengenol* 89 (1963) 847
- OHLESEN E G and ARONSEN K F Carcinoma of the gallbladder A review of 111 cases To be published in *Acta chir scand* 1973
- POLK H C Carcinoma and the calcified gallbladder *Gastroenterology* 50 (1966) 582
- REUTER S R, REDMAN H C and BOOKSTEIN J J Angiography in carcinoma of the biliary tract *Brit J Radiol* 44 (1971) 636
- ROSCHE J, GROLLMAN JR J H and STECKEL R J Arteriography in the diagnosis of gall bladder disease *Radiology* 92 (1969) 1485
- SCHITZ H R, BADRICH W E, FROMMOLD W, GLAUSER R, UEBELVOER H und WELLSER J Hrsg. Lehrbuch der Röntgendiagnostik Band V 6 neubearb. Aufl Georg Thieme Verlag Stuttgart 1963
- SPRAYregen S and MESSINGER N H Carcinoma of the gallbladder diagnosis and evaluation of regional spread by angiography *Amer J Roengenol* 116 (1972) 382
- STRACI G O Primary carcinoma of the gallbladder Presentation of seventy cases from the Rhode Island Hospital and cumulative review of the last ten years of the American literature *Surgery* 47 (1960) 368
- TABAH E J and MCNEER G Papilloma of the gallbladder with in situ carcinoma *Surgery* 34 (1953) 57
- TATERKA H Cholezystiographische Untersuchungen mittel: Decholzdehnung und Eigelbentleerung *Röntgenpraxis* 3 (1931) 721
- WETZ W Angiographische Darstellung der Gallenblasenarterien *Fortschr Röntgenstr* 106 (1967) 387
- ZAWADOWSKI W und FLEWNIAK W Gallenblasenkrebs mit Kalkablagerungen und Porzellangallenblase im Röntgenbild *Röntgenpraxis* 8 (1936) 318

ARTHROGRAPHY OF THE KNEE WITH A MODIFIED TECHNIQUE

HANS LEVEN

The conventional method of examination of the knee joint consists of stereoscopy in various degrees of rotation after the injection of a contrast medium and enucleate having previously been drained lateral films with the tibia drawn forwards (drawer sign test) are also taken. The examination is usually carried out on a Lyscholtz skull table, a Mimer apparatus or the like, it was described by LOMBARD (1948). Other methods have been published as well, e.g. the so-called double contrast method of Van De Berg which combined with fluoroscopy and slight varus/valgus flexion has been described by ZARINSKY (1960), no information of how the knee joint could be forced into the drawer sign position was however given.

A modified technique for arthrography of the joint which produces a better representation and easier interpretation than obtainable hitherto is now described.

Fluoroscopy is performed with an over couch tube that can be adjusted by remote control. This enables the beam to be brought parallel to the joint space without altering the position of the leg. The immobilization of the knee joint with a constant static force is performed by slings placed round the leg and attached to the edge of the table with jam cleats (Fig. 1). The advantage compared to earlier methods of immobilization is the ease with which the slings

Submitted for publication 26 April 1973



Fig. 1. a) The immobilizing arrangement applied to obtain valgus position; b) Tibia forced (drawn) inward; c) Close-up of the fastening of the line to the edge of the table joint.

are locked to the edge of the table for the drawer sign position. A series of a picture film is obtained with forced varus and another with forced valgus position, with inward and outward rotation. The tibia is forced backward and forwards for the lateral series.

The diagnosis of rupture of the meniscus with fragment interposed between the two condyles is based on, among other things, the presence of an increased amount of contrast medium appearing as a broad band between the condyles. A potential source of error in the diagnosis is that the lower leg may lie in the varus or valgus position. This may displace the two condyles apart and produce a similar increase of contrast medium between them, erroneously indicating the interposition of meniscal fragments. By intentionally applying force tending to produce these positions, the possibility of such a diagnostic error may be eliminated. In addition fragments of the menisci may separate better and the meniscal ruptures may thus be recognized more often in a forced valgus or varus position (Fig. 2).

Ruptures of the cruciate ligaments are best seen in lateral projections with the tibia pulled forwards and backwards (Figs 3-4). The immobilizing arrangement enables steady and powerful forward traction on the tibia to be applied without discomfort to the patient. A positive drawer sign may readily be obtained. Whereas previously the tibia was pulled manually by the examiner who thus remained in the room during the exposure, the present technique enables the staff to leave the patient's side after immobilizing the knee joint.

Primary dodging is effected with the Dodger T apparatus (LÖNNHOLM & JACOBSSON 1971-1972). This has improved the demonstration of the peripheral



Fig 2 Rupture of the medial meniscus a) Varus position the rupture is not visible
b) Valgus position the rupture is demonstrated



Fig 3 Normal findings Drawer test with the tibia pulled a) backwards the anterior cruciate ligament is difficult to appreciate b) forwards the anterior cruciate ligament is stretched and now obvious



Fig 4 Total rupture of the anterior cruciate ligament a) without drawing the tibia forward b) with the tibia drawn forwards



Fig 5 Rupture of the medial meniscus and extraarticular leakage of contrast medium. The beneficial effect of dodging is evident.

parts of the joint and increased the possibility of diagnosing the rupture of collateral ligaments (Fig 5).

The Lindblom method for arthrography of the knee is a most satisfactory one and 95 per cent reliable in the diagnosis of ruptures of the meniscus (LINDVALL 1972). It would appear however that the technique now described can further improve and facilitate the diagnosis of ruptures of the menisci and especially of ruptures of the cruciate ligaments.

SUMMARY

A modified technique for arthrography with a positive contrast medium is presented. An immobilizing device in addition to fluoroscopy dodging is used to fix and subject the knee joint to different constant static forces during the exposure.

ZUSAMMENFASSUNG

Es wird eine modifizierte Technik zur Arthrographie mit einem positiven Kontrastmittel präsentiert. Zusätzlich zur Durchleuchtung und den primären raschen Randbewegungen wird eine Anordnung zur Immobilisierung des Kniegelenks verwendet, um dieses zu fixieren und während der Exposition verschiedenen konstanten statischen Kräften aussetzen.

RÉSUMÉ

Présentation d'une technique modifiée d'arthrographie à contraste positif. L'auteur utilise en plus de la radioscopie un dispositif qui immobilise l'articulation du genou qui le soumet à différentes forces statiques constantes au cours de l'exposition et qui permet une exploration primaire de la partie de la région du genou.

REFERENCES

- LINDBLOM K. Arthrography of the knee. *Acta radiol* (1918) Suppl. No. 74.
- LINDVALL N. Arthrografi vid ledskador. (In Swedish.) *Tonnske Läkareförn* 90 (1961) 928.
- EDHOLM P. and JACOBSSON B. Primary X-ray dodging. *Radiology* 99 (1971) 691.
- — Methoden für primären Diagnostikknieschleich. *Röntgenpraxis* 24 (1972) 183.
- ZARLHOFER U. Meniscography by Van De Berg: double contrast technique. *Acta radiol* 53 (1960) 442.

THE TORTUOUS BASILAR ARTERY

M HAVERLING

The basilar artery often forms a regular arch to one side a variation that makes it virtually impossible to diagnose an expanding lesion solely from a lateral displacement of the vessel (LENDOREN 1954 GREITZ & LENDOREN 1961) The course of the basilar artery has therefore become of secondary importance OLSOY (1953) in an evaluation of vertebral angiography in acoustic nerve tumours observed that the vascular pattern varied widely from one case to another The basilar artery however failed to deviate towards the tumour side in 10 and was situated in the midline in 4 of the 14 cases reported

Investigations have been carried out both in the venous and the arterial systems to determine the cause for the tortuous appearances of certain blood vessels (NYLANDER 1969 RICKENBACHER 1964 ZULCH 1962 EICHORN & SCHLICHT 1969)

The tortuosity of the blood vessels is caused mainly by the meandering phenomenon in both systems (LEOPOLD & WOLMAN 1960 LEOPOLD & LANGBEIN 1966) The tortuosity tends to be more marked in the older age groups apparently due to a decrease of elasticity in the arterial wall which starts gradually after the age of twenty (ROSSLY & ROULET 1932) The meandering phenomenon and the loss of elasticity in the blood vessel wall probably explain the

From the Department of Neuroradiology (Director Prof T Greitz) Karolinska sjukhuset 104 01 Stockholm Sweden Submitted for publication 5 June 1973

Table
Age distribution of patient material

	Years						
	0-10	11-20	21-30	31-40	41-50	51-60	61-70
Number	0	12	22	14	21	11	8

curvature of most vessels in adults. Other effects may however cause the vessel to leave its physiologically most suitable straight course after the confluence or before the division of certain vessels. This may be apparent after the union of the vertebral arteries to form the basilar artery. The irregular appearance of this vessel starts early and may be detected in the foetus.

A small investigation of vertebral angiographies indicated that the course of the basilar artery was caused by three main factors: namely (1) the loose connections between the basilar and the vertebral arteries and the surrounding tissues; (2) the difference between the blood flow in the right and left vertebral arteries; and (3) the directions of these blood flows compared to each other and the most natural course of the basilar artery along the mid sagittal plane of the skull. By estimating the blood flows through the vertebral arteries and their directions just before the confluence of these vessels, it should be possible to make rules to indicate the probable direction of the basilar artery. The course of this artery could perhaps be utilized more frequently in the diagnosis of expanding processes in the posterior cranial fossa.

Material and Method. The course of the basilar artery and the diameters of the vertebral arteries were estimated from two different sources: (1) Angiograms obtained by the injection post mortem of a barium contrast medium into the cerebral arteries of 8 foetuses from 15 to 49 centimeters in length; (2) films from 100 normal vertebral angiographies.

All the foetal vessels examined were well demonstrated in all the angiographies. The films from the patient material were chosen according to the following rules: (A) The angiography had to be carried out with a catheter introduced into one of the vertebral arteries following transfemoral percutaneous puncture (LUNDGREN 1956). (B) Adequate demonstration of the basilar artery and the upper parts of the vertebral arteries (usually from the first cervical vertebra) was necessary. (C) The angiograms must have been obtained in satisfactory projections (at least one true a.p. or one half axial film).



Fig 1 Accessory lines utilized during the measuring procedure. Vertebral artery diameters were measured at d and the distance between the midline of the basilar artery from b to the mid sagittal plane s—s and the vertebro basilar junction to the same plane

The age distribution of the patients appears in the Table

The course of the basilar artery was determined by measuring the distance from the mid sagittal plane of the skull to (a) the midline of that part of the vessel with the greatest deviation, (b) the union of the vertebral arteries and (c) the division of the basilar artery (the bifurcation). The side of the mid sagittal plane on which these points were situated was noted (Fig 1). The diameters of the vertebral arteries were measured following a method described for the carotid artery by GABRIELSEN & GREITZ (1970). As it was not always possible to measure the diameters of the vertebral arteries exactly at their union with the basilar artery diameters for this purpose were selected from about 1 to 2 centimeters below the vertebro-basilar junction.

No measurements of the basilar artery were made in the foetal angiograms only its appearances being recorded. The diameters of the vertebral arteries were measured in two such angiograms in magnifications made with a communication set (H Q Vidicon camera-chain, Type EL 810 815 Philips). The measurements stated in millimeters were obtained by measuring the magnified vessels directly on the TV screen. Sixteen vertebral angiographies from the patient material with small differences of the vertebral artery diameters were selected. The angle between the mid sagittal plane and the direction of the vertebral arteries in their last sections before their union were measured with a protractor.



Fig. 2 Fetal angiograms. a) Basilar artery with a straight course. b) Smallest foetus with slight deviation of the basilar artery. c) Largest foetus with marked arching deviation of the basilar artery.

Results

The course of the basilar artery was completely straight in six of the eight foetal angiographies (Fig. 2 a). The diameters of the left and right vertebral arteries as well as the inflow direction towards the basilar artery were symmetric in these six cases. In one of the foetuses, the smallest one (15 cm), the basilar artery deviated slightly to the right; the diameter of the right vertebral artery was 3 mm while that of the left was 3.5 mm as measured on the TV screen.



Fig. 3 Four basilar arteries apparently not conforming to the rule of deviation. It is possible that critical arteries may be explained partly by ectatic elongation of the vessel.

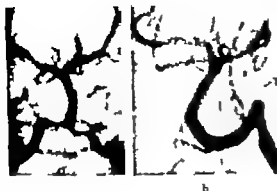


Fig 4 Vertebral angiograms. Example of common arched displacement of the basilar artery caused by the blood flow of the greater vertebral artery (See also Fig 5)

(Fig 2 b) The largest foetus (49 cm) had a basilar artery with a large arched deviation to the right and displacement of the bifurcation in the same direction. The vertebro basilar junction appeared to be situated in the mid sagittal plane. The diameter of the right vertebral artery was 3 mm while that of the left was 8 mm (Fig 2 c)

The vertebral artery had the same diameter on both sides in five patient angiographies. The angles between these vessels and the mid sagittal plane were identical and the basilar artery was straight. Arched deviation of the basilar artery to the side opposite to that of the larger vertebral artery was evident in 78 patients.

The angle between the vessels and the mid sagittal plane was measured in 12 patients with no or very small differences in the diameters of the vertebral arteries. It was apparent that the basilar artery deviated to the side contralateral to the vertebral artery that formed the largest angle to the mid sagittal plane.

The course of the vessels did not seem to follow these simple rules in the 4 cases illustrated in Fig 3.

The course of the vertebral and basilar arteries was even more complicated in a further case, however this patient was operated upon for a right sided carotid aneurysm before the vertebral angiography was performed which may have influenced the position of the vessels.

Discussion

The primary pre requisite for the basilar artery to become tortuous is loose connections between the vessel and the surrounding tissues. This factor however only allows the vessel to be more easily influenced by the haemodynamic forces — the amount of blood flowing through the vessels per unit time, the velocity of

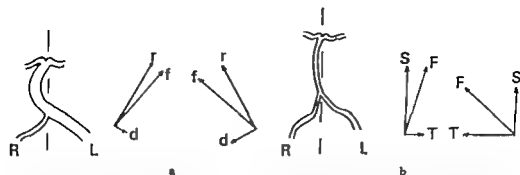


Fig 5 The influence of blood flow forces with different blood flows through the vertebral arteries and counter directions of flows a) The same blood flow but different opposed directions of flow b) $r =$ rate of blood flow d and d' diameter of vertebral artery f and f' approximated blood flow forces The basilar artery will be forced by f to the right b) $F = F'$ May be divided into sagittal forces S and S' and transverse forces T and T' The basilar artery will be forced by T to the right

the blood flow and the direction of inflow into the basilar artery. The basilar artery may therefore be shaped according to the influences of these forces. As the vertebral arteries arise from the same primary vessel, the aorta, and join to form one single vessel, variations in blood flow through them relate to differences in their diameters. The direction of the blood flow, which is determined by the direction of the vessel, is reflected by the angle between the vertebral artery and the mid-sagittal plane as evident in the a.p. projection. It was thus possible in a simple manner to judge approximately the size and direction of these blood flows.

Basilar artery deviation proved to be related to the diameters and directions of the distal parts of the vertebral arteries. The most common cause of deviation was a difference in blood flows (Fig 5 a). The blood flow force acting on the basilar artery may depend upon the flow rate (r and r') and the amount of blood streaming through the vessels. Since the rate of the blood stream through the vertebral arteries is probably similar on both sides, the only variable will be the diameter of the vertebral artery and thus the cross-sectional area of this vessel (d and d'). d is larger than d' and therefore the resultant f will be smaller than f' . The force of the blood stream on the left side will be greater than that on the right side, to which the basilar artery will deviate.

The second cause of basilar artery deviation is illustrated in Fig 5 b. The blood flows through the vertebral arteries were similar, but the left vessel was more angulated to the mid-sagittal plane than the right. The blood flow forces F and F' were similar; they may be divided into one sagittal and one transverse force. The left vertebral artery transverse force T will then be greater than the right one T' and the basilar artery will, therefore, deviate to the right.

No difference in the diameters and angles of the vertebral arteries were established in 5 patients and the basilar artery ran a straight course. In the largest group of 78 patients arched deviation of the basilar artery counter to the direction of the largest vertebral artery blood flow was present with marked differences in the diameters of the vertebral arteries. The appearances of the basilar artery in these two groups made up of 83 of the total of 100 patients indicated that it is primarily the blood flow through the vertebral arteries that determines the deviation of the basilar artery (Fig. 4). This is also illustrated by the appearances of the vessels in the foetal angiograms (Fig. 2).

Twelve patients had very slight differences in the vertebral artery diameters and thus small variations between the blood flows through these vessels. It was possible though to detect a relationship between the angles of the vertebral blood vessels to the mid sagittal plane and the deviation of the basilar artery. This vessel thus deviated counter to the side of the vertebral artery forming the largest angle to the mid sagittal plane.

In only 5 patients did the vessels have such appearances that it was impossible to state the cause of the deviation of the basilar artery from only the factors given above. One of these patients had been operated upon for an aneurysm of the right carotid artery and it was impossible to judge the changes the intervention had caused intracranially. The course of the basilar arteries in the other patients seemed to defy categorizing as to cause (Fig. 3). If however the positions of the vertebral arteries in relation to the mid sagittal plane were ignored it was evident that the shape of the basilar artery was still determined by the amount of blood flowing through the vertebral arteries and the directions of these blood flows just before the cerebro-basilar junction.

The investigation in the foetuses indicates that the shape of the basilar artery may be established early. It was possible in these angiographies to correlate the relationship between the appearances of the vessels and the above mentioned haemodynamic forces. The fact that most angiographies in the foetal material depicted a basilar artery with a straight course was probably due to the circumstance that the vessels were usually not completely developed and the diameters were thus still small. The differences in the diameters and blood flows were therefore also small and had little influence on the course of the basilar artery. When proportionally similar differences in vessel diameters and angles occur in foetus and in adults the variation in flow rates in absolute figures for a given deviation will be greater in adults and a correspondingly greater increase of basilar artery displacement will result. Ectatic changes in the foetal vessels following lack of elasticity in the arterial wall is not to be expected furthermore deviation of the basilar artery exists in an early stage of development. It therefore appears reasonable to suggest that ectatic changes are of secondary importance in the forma-

tion of these displaced vessels. Because of limited patient material no correlation between age and increased deviation of the basilar artery was attempted, though probability speaks in favour of increasing deviation with increasing age due to ectatic changes. It is likely that the tortuosity of the vessels illustrated in Fig. 3 was due at least partly to ectasia causing their marked elongation. The arched course in two of these cases definitely conforms however with the direction of flow in the vertebral arteries.

Conclusions

Two main factors seem to determine the course of the basilar artery in normal subjects: (1) the amount of blood streaming through the vertebral arteries as sensed by measuring the diameters of these vessels in their terminal sections just before their union to form the basilar artery; (2) the direction of the blood stream through the terminal parts of the vertebral arteries determined by measuring the angle between the midline of each vessel and the mid sagittal plane of the skull.

The basilar artery courses away from that vertebral artery with the largest blood flow and the steepest angle to the mid sagittal plane.

SUMMARY

The appearances of the basilar artery were examined post mortem in 8 foetal angiographies and in films from 100 vertebral angiographies considered normal. The commonly noticed arched displacement of the artery to one side seemed to be due mainly to differences in blood flow through the vertebral arteries and its direction in relation to the mid sagittal plane of the skull.

ZUSAMMENFASSUNG

Die Erscheinungsformen der Arteria basilaris wurden post mortem in 8 foetalen Angiographien und an Filmen von 100 als normal befundenen vertebralen Angiographien untersucht. Die gewöhnlich gebogene Verschiebung der Arterie nach einer Seite scheint hauptsächlich auf dem Unterschied im Blutstrom durch die Vertebralarterien und der Richtung im Verhältnis zum Mitteln-Sagittalplan des Schädels zu beruhen.

RÉSUMÉ

L'auteur a examiné les aspects du tronc basilaire sur huit angiographies post mortem de foetus et sur des films de 100 angiographies vertébrales considérées comme normales. Le déplacement fréquent en arc de cette artère vers un côté paraît dû principalement à une différence du courant sanguin dans les artères vertébrales et à sa direction par rapport au plan sagittal médian du crâne.

REFERENCES

- EICHENORN O and SCHLICHT L The importance of hydraulic principles in the regulation of cerebral blood flow. *I Research on the cerebral circulation Third International Salzburg Conference* p 332 Charles C Thomas Springfield Illinois 1969
- GABRIELSEN T O and GREITZ T Normal size of the internal carotid middle cerebral and anterior cerebral arteries. *Acta radiol Diagnosis* 10 (1970) 1
- GREITZ T and LINDQVIST E Cerebral angiography. *I Angiography Volume I section II* p 41 Edited by H L Abrams Little Brown & Co Boston 1961
- LEOPOLD L B and WOLMAN M G River meanders. *Bull Geol Soc Amer* 71 (1960) 769
- and LINDQVIST W H River meanders. *Scient Amer* 6 (1966) 60
- LINDQVIST E Röntgenologie. In *Handbuch der Neurochirurgie* S 171 Herausgegeben von H Olivcrona und W Tonnies Springer Verlag Berlin Göttingen Heidelberg 1964
- Another method of vertebral angiography. *Acta radiol* 46 (1956) 257
- NYLANDER G The meandering phenomenon in the pathogenesis of varices. *Angiology* 20 (1969) 592
- Meanders of the great sphenous. *ein Angiology* 20 (1969) 587
- The morphology of early meanders of the great sphenous. *ein Angiology* 20 (1969) 601
- OLSSON O Vertebral angiography in the diagnosis of acoustic tumours. *Acta radiol* 29 (1953) 270
- REICHENOW J Der subocspitale und der intrakranielle Abschnitt der Arteria cerebri. *Z Anat Entwickl Gesch* 124 (1964) 171
- ROULE R und ROULE F Masse und Zahl in der Pathologie Springer Berlin 1952
- ZOLNER K J Pathogenesis of disturbances of cerebral blood flow. *Int J Neurol* 3 (1962) 464

EKG ECG AND OTHER RECORDINGS IN CEREBRAL ANGIOGRAPHY

K. TALLE and A. LUNDERVOLD

Cerebral angiography is not completely without risk as many of the subjects are old and suffer from vascular disorders. Careful observation of neurologic reactions is therefore important and routine recordings of EEG and ECG and sometimes of the EMG, blood pressure and respiration as well are required in most of the examinations. Patients considered to be susceptible to complications have been primarily selected for this investigation the results of which to 1967 have been previously reported (LUNDERVOLD et coll 1964 LUNDERVOLD & FROESER 1966 1969 LUNDERVOLD & ONORI 1968) while those for 1968 to 1971 are now presented.

The dose of contrast medium reduced from 10 to 7 ml in December 1964 was again increased to 9 ml in order to take advantage of the improvement in technique and the reduction in complications achieved since 1962. This was possibly the cause of a slight deterioration in the polygraphic parameters as well as of an apparent increase in reactions. Intensive clinical control of all patients was instituted to examine this more thoroughly. The EEG and ECG were recorded in most of the patients. The results to the middle of 1972 are now reported and compared with the routine polygraphic investigations up to 48 months previously.

Table 1

Findings in polygraphic recordings 1968-1971

Year	Total	Men	Women	Total n	Carotid angio- graphy	Verte- bral angio- graphy	Aorto- graphy	Changes		ECG	
								EEG	ECG		
								No	N		
1968	438	239	199	768	354	71	85	3	0.38	3	0.38
1969	43	269	134	673	297	88	38	1	0.15	1	0.15
1970	550	344	206	854	430	106	14	5	0.39	0	0
1971	698	418	282	921	567	190	11	12	1.30	2	0.29
	2109	1268	841	3238	1628	38	96	21	0.65	6	0.19

Method and material Percutaneous transfemoral introduction of either a standard carotid catheter id 0.47 mm or a vertebral catheter id 0.45 or 0.47 mm was performed. Special catheters were used for infants and small children. It has seldom been necessary to puncture the carotid artery. The patient was premedicated with atropine and amobarbitalum with mannitol if increased intracranial pressure was probable. Only children and nervous adults were anaesthetised. Iopaque Cerebral was injected in a dose of 5 ml for vertebral angiography and of 7 ml for carotid angiography; this was increased gradually to 9 ml in 1970 but reduced again to 7 ml from early 1972 because of a slight increase in complications.

Routine polygraphic recordings were made in 2109 patients (1268 men and 841 women) with a total of 3238 injections during the period 1968 to 1972 (Table 1). The intensive clinical control covered 554 patients (323 men and 231 women) for 13 months to the middle of 1972. Of these 42 had simple aortographies and the remaining 512 patients had selective angiographies in which more than one vessel was usually examined at the same session. A total of 419 patients (75.6 per cent) had a dose of 9 ml and the 135 patients (24.4 per cent) who followed had 7 ml of medium. The EEG and ECG were also recorded for most of these patients and this material is included in the result of the routine polygraphic recordings before the end of 1971; some overlapping of the material compared thus occurred.

The changes during the routine recordings in the period have been below 1 per cent for both the EEG and ECG except in 1971 when the percentage for the EEG increased to 1.3 (Table 1). This was the first full year at the increased dose (9 ml) and the raised frequency was the reason for instituting the clinical

control Twenty five of the 554 patients in the control had temporary and usually short lived reactions Four of these were allergic reactions to the contrast medium (urticaria) two were reactions to the local anaesthetic, and another patient had an attack of angina pectoris during the preparations for the radiographic examination in four of the remaining 18 cases the reactions occurred before injection of the contrast medium, giving a frequency of 3.2 per cent

Most complications occurred between the ages of 40 to 60 years nearly all the patients examined were also in this range The youngest with complications was 23 and one case with paralysis was only 25 years old The frequency of complications was surprisingly higher in women (14 out of 231) than in men (only 4 out of 323) This is difficult to explain A total of 18 reactions were recorded none in patients who had had a general anaesthetic Four of the reactions arose before the contrast medium was injected and it is reasonable to assume that they were due either to manipulation of the catheter and possible dislodgment of emboli or to the triggering off of some form of vasomotor effect One of the patients had one of his recurrent epileptic fits which presumably had no connection with the examination itself A probable cerebrovascular defect was present before the examination in 2 of the patients while another had recently been operated on for subarachnoid bleeding all 3 were in poor condition The fourth had a possible tumour or arteriovenous malformation and had previously undergone cerebral angiography without any complication

One of the 14 reactions that arose after the procedure was due to haemoptoeia caused by the subintimal injection of the medium and partial occlusion of the carotid artery the paralysis disappeared after about a day

There thus remain 13 patients in whom it is possible that the reaction may have been produced by the contrast medium itself in addition to any other factors Only 2 of these reactions occurred after the reduction to the dose of 7 ml and were only trivial (nausea and vomiting) The group is however small and more serious reactions have been observed with this dose after the present material was completed The duration of the effects was short from minutes to a few days except in a patient with slight dysphagia and facial paresis in whom they lasted three weeks thus no patients had demonstrable permanent sequelae Fifteen reactions were observed in the roentgen department while 3 were first noticed after the patient had returned to the ward Eight of these patients had complications that were so slight and of such short duration that they would almost certainly have been missed if the intensive clinical control had not been made This emphasizes that close control of the patient during and immediately after the roentgen examination is essential BRINZ *et al* (1971) have also reported slight transient neurologic reactions that would have passed unnoticed if they had not been specially sought

Tabl. 2

Incidence of reactions before and after reduction of contrast dose from 9 to 7 ml

Reaction	No. of patients	% of record age	No. of EEG worse	No. of EEG normal or unchanged	Not recorded
A. Dose 9 ml					
Hemiparesis, paralysis or paresthesia	6	4	4	0	2
Visual disturbances	5	4	1	3	1
Nausea	1	1	1	0	0
B. Dose 7 ml					
Nausea or dizziness	2	2	1	1	0
Total	14	11	7	4	3

Polygraphic recordings were made as a routine usually before, during and after the injection in patients in poor condition and those in whom experience had indicated might have been the most liable to reactions. A detailed description of the technique and the previous results appears in earlier publications by the authors (LUNDERVOLD & ØVRE 1968, LUNDERVOLD & ENOSET 1969). Most patients had one or more routine EEG recordings before the neuro-radiologic examination and some patients had these following it as well.

Two of the 4 patients with neurologic reactions before the injection were examined polygraphically. The EEG in one patient revealed focal changes as delta activity and spikes over the right frontoparietal region, this is in agreement with the occlusion of the right internal carotid artery which was subsequently confirmed radiologically. The EEG disclosed generalised dysrhythmia in addition to the focal changes when the patient became unconscious before the injection, the condition was improved rather than deteriorated by the administration of the contrast medium (9 ml). The other patient had been operated on for an aneurysm of the left anterior cerebral artery. The EEG before the radiologic examination indicated generalised cerebral dysrhythmia. Before the cerebral angiography the patient had an epileptic attack and was unconscious for a day. This had apparently happened before so that the relation to the roentgen examination was doubtful. EEG recorded several days later revealed moderate focal delta activity over the left frontotemporal region.

Eight of the 14 patients with reactions after the injection had previously had EEG before, 8 during and 8 after the examination was completed. However, only five reactions were recorded before, during and after the examination.

Four reactions were recorded twice and 2 only after the examination. 3 were not recorded at all (Table 2). EEG recordings were made before, during and after the examination in 1 of 6 patients with hemiparesis, paralysis or aphasia; all became considerably worse. The EEG in a patient with N. abducens paresis was normal before the examination but the injection provoked left hemiparesis with dysphasia that lasted for three weeks and the EEG revealed theta activity over the central part of the right hemisphere. A patient with epilepsy had spike wave complexes without asymmetry in the EEG before the roentgen examination. Transient right hemiparesis appeared after the injection of contrast medium (into the left carotid artery) and lasted for about half an hour. Both the polygraphic and a subsequent EEG recording disclosed focal theta activity and reduced background activity over the left side especially in the temporal region. One patient had been operated on three years earlier for a meningioma of the right frontal region. Before the radiologic examination the EEG disclosed a marked delta focus with individual sharp waves over the right frontotemporal region; this increased after the subintimal injection of contrast medium to produce left hemiparesis of about 24 hours duration. Another patient, one with a pharyngeal neoplasm, had aphasia for two days after the injection with evidence of focal activity over the left temporal region in the EEG.

Five patients had visual disturbances some minutes after the injection. Moderate generalised cerebral dysrhythmia was evident in the EEG during and after the injection in one of these with a meningioma of the right parietal lobe. The only symptom in the remaining 3 patients was slight nausea or dizziness for some hours up to 3 days; in one the EEG was unchanged and in the other two slight deterioration occurred in the form of generalised cerebral dysrhythmia.

Discussion

The complications of cerebral angiography (most commonly transitory hemiparesis with carotid angiography and disturbances of vision and consciousness with vertebral angiography (HALOR 1954)) have been variously reported to be from 2 to 19 of a temporary and 0.8 to 3.7 per cent of a permanent nature (FIELD *et coll.* 1962; PATTERSON *et coll.* 1964; LAVITRAS & WOOD 1964; FLETCHER & NISHIMURA 1966). SILVERSTEIN (1966) has pointed out that patients over 60 and those with cerebrovascular disease or other cardiovascular lesions carry an increased risk. Since 1962 the frequency and severity of complications have steadily decreased in our department from 16 per cent with changed EEG to 1 per cent in 1967 and from 19 per cent with EEG changes to 2 per cent in 1967. These have further decreased to less than 1 per cent in the period now reported except when the dose was increased. It would appear that this reduction in the

frequency of reactions has been due to an improved technique and better contrast media. The importance of reducing the dose of medium to the minimum was stressed by LUNDVOLD & ENGET (1966) who reported that the incidence of EEG and ECG changes decreased when the dose was lowered from 10 to 7 ml. They also demonstrated a reduction in EEG and ECG changes when Isopaque 45 % (sodium metrizoate no longer marketed) was replaced by Isopaque II (sodium metrizoate balanced with calcium and magnesium) and a further reduction when Isopaque Cerebral was introduced compared with Isopaque B and Urografin. The number of injections has also been decreased now that films are taken in two planes simultaneously.

Since the incidence of complications had become so low a trial was made of raising the dose again from 7 to 9 ml. The frequency of complications then appeared to increase so that the dose had to be returned to 7 ml. The increase in complications could have resulted from more patients with cerebrovascular disease or otherwise in poor condition. This could not however have been concluded with any certainty.

Conclusion

The continuous polygraphic recording of patients considered most likely to suffer complications from cerebral angiography in the period 1968 to 1971 has confirmed the constant decrease in the frequency of EEG and ECG changes except for 1971 when a slight increase possibly associated with an increase in dose made at the end of 1970 was noted. Extensive and detailed clinical examination of all cerebral angiography patients over a period of 11 months has disclosed 18 out of 554 patients with temporary most often short lived reactions such as hemiplegia, aphasia and visual disturbances. Many of these reactions would never have been noticed but for the close clinical observation in the roentgen department. Such control, together with polygraphic recording should reveal the slight transitory reactions that occur. These may possibly increase with the more active approach to the surgery of aneurysm and to operations on older subjects as well as on those in poor condition.

SUMMARY

Recordings of EEG, ECG and also occasionally of EMG and blood pressure during cerebral angiography performed in 2109 patients during 1968 to 1971 have revealed reduction in the occurrence of abnormalities when compared with the 1000 patients examined before 1967 and reported in 1969. Polygraphic recordings have now shown minimal changes in less than 1 per cent. A more extensive clinical control of the patients revealed some slight transitory reactions not all seen in the recordings. The significance of the type and amount of contrast medium is discussed.

ZUSAMMENFASSUNG

Registrierungen des EEG, EKG und auch gelegentlich des EMG und des Blutdrucks während der cerebralen Angiographie die bei 2109 Patienten zwischen 1968 und 1971 vorgenommen worden waren, ergaben ein verminderstes Auftreten von Komplikationen verglichen mit den 1000 vor 1967 untersuchten Patienten, wosüber 1969 berichtet worden ist. Die polygraphischen Registrierungen zeigten jetzt minimale Veränderungen bei weniger als 1%. Eine genauere klinische Kontroll der Patienten ergab einige leichtere oder bergebende Reaktionen, die nicht alle bei den Registrierungen zu sehen waren. Die Bedeutung der Art und Menge des Kontrastmittels wird besprochen.

RÉSUMÉ

Les enregistrements d'EEG, d'EKG et aussi dans certains cas d'EMG et de la pression sanguine, cours d'angiographie cérébrale effectués chez 2109 patients entre 1968 et 1971 ont montré une réduction de la fréquence des anomalies par comparaison avec les 1000 patients examinés avant 1967 et publiés en 1969. Ces coregistrements polygraphiques ont montré actuellement des modifications minimales dans moins de 1% des cas. Un contrôle clinique plus complet des malades a montré quelques réactions transitoires légères qui n'étaient pas toutes mises en évidence par les enregistrements. Les auteurs examinent l'importance de type et de la quantité de moyen de contraste.

REFERENCES

- BRINZ, C. D., BERNSTEIN, D. C., BOTH, A. E., McCALL, I. R., MARGERSON, J. H. and SCOTT, J. I. Clinical and electroencephalographic sequelae of carotid angiography. *Acta radiol. Diagnosis* 11 (1971) 626.
- FELD, J. R., ROBERTSON, J. T. and DeSAULNIER, R. L. Complications of cerebral angiography in 2000 consecutive cases. *J. Neurosurg.* 19 (1962) 773.
- HALOE, R. Catheter vertebral angiography. *Acta radiol.* (1954) Suppl. N. 109.
- LUNDERVOLD, A. and ENOSET, A. Polygraphic recordings during cerebral angiography. *Acta radiol. Diagnosis* 5 (1966) 368.
- — Electroencephalographic and electrocardiographic studies of complications in cerebral angiography. *Acta radiol.* 9 (1969) 999.
- — and PASTRINIS, J. Cerebral angiography and pneumoencephalography. A polygraphic investigation. *Europ. J. Neurol. Psychiat.* 3 (1964) 129.
- and ONORI, A. Polygraphic recordings in cerebral angiography with meglumine metrizoate and meglumine iohalumar. *Farmacoterapi* 24 (1968) 3.
- PATTERSON, R. H., GOODILL, H. and DUNNIN, H. S. Complications of carotid arteriography. *Arch. Neurol. (Chicago)* 10 (1964) 313.
- FARRET, G. and NISHIOKA, H. Report on the cooperative study of intracranial aneurysms and subarachnoid hemorrhage. *J. Neurosurg.* 25 (1966) 98.
- SPRISTIN, A. Arteriography of stroke. III. Complications. *Arch. Neurol. (Chicago)* 15 (1966) 206.
- TAUVRAS, J. M. and WOOD, F. H. *Diagnostic neuroradiology*. Williams & Wilkins Co. Baltimore 1964.

ABDOMINAL DIMENSIONS AND THICKNESS OF THE SUBCUTANEOUS FAT IN THE FETUS

U ERASMIE and H G RINGERTZ

Appreciation of the thickness of the fetal subcutaneous fat constitutes part of the roentgen assessment of fetal maturity. The literature appears to contain no roentgen investigation of the subcutaneous fat layer of the fetus in the later stages of pregnancy; this applies both to fetus of normal and diabetic mothers. RINGERTZ (1971) described a method for determining fetal weight by roentgen measurements of the abdominal diameter (A) and the lumbar vertebral length (V). It was believed that the quotient A/V might be of clinical significance in, for example, maternal diabetes: neonates of diabetic mothers have higher average weights than normal newborns (HSIA & GELLIS 1957) and this might be associated with different body proportions. The thickness of the abdominal subcutaneous fat and the A/V quotient were consequently investigated.

Material and Methods The normal appearances and magnitude of the above factors were investigated in 130 cases in which (1) no abnormalities of mother or child had been recorded, (2) the uterus contained no more than one fetus. The roentgenograms were reviewed in retrospect. The reason for the examination was usually uncertainty about the length of gestation and risk of overdue.

Submitted for publication 24 May 1973



Fig. 1. Roentgenogram of fetus in the tenth gestational month. Measurements of the abdominal diameter (A) and lumbar vertebral length (V) (long arrows) and the thickness of the subcutaneous fat at the level of L1 (short arrows).

delivery. Roentgenograms of 36 fetuses of diabetic mothers were also analysed. No attempt at subdivision of this group was made neither as regards the severity of maternal diabetes nor type of treatment. All mothers were carefully controlled during pregnancy and thus probably on adequate drug therapy.

The average calculated weight (RINGERTZ 1971) at the roentgen examination was $3\,304 \pm 561$ g for the normal cases. The corresponding figures for the fetuses of diabetic mothers were $3\,253 \pm 631$ g.

All measurements were made from routine films in millimeters with an estimated error of under one millimeter. No enlargement factor has been accounted for in the calculations. The only roentgenogram used was obtained with the mother lying on her side with a compressor reducing the depth of tissues to be penetrated by the rays (EDHOLM 1956). The vertical focus-film distance was 100 cm.

The measurements of the fetal abdominal diameter (A) and the lumbar vertebral length (V) (RINGERTZ 1971) as well as the thickness of the subcutaneous fat at the level of the first lumbar vertebra perpendicular to the spine were recorded (Fig. 1). This thickness could be measured on both sides of the abdomen in 93 and on one side in 37 normal cases. The corresponding figures in the diabetic group were 78 and 8.

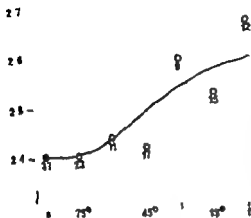


Fig. 1. Plot of the average A/V quotient (y axis) for different rotational aspects of the fetus (x axis). The figures represent number of measurements included in each mean. The curve indicates the best least squares fit to the values giving average transverse to craniocaudal abdominal diameter proportions of 1.064 : 1.

The angle of rotation of the fetal body around its long axis relative to the mother was estimated. The appearances of the fetal skeleton determined the grouping of the cases: 0 (37), 15 (23), 30 (11), 45 (18), 60 (9), 75 (18) and 90 (14). The figures within brackets indicate the number of cases in each group. 0 stands for an a.p. projection of the fetal body and 90 for a true lateral view.

The calculated weight (Risserwitz) and not the birth weight was used throughout. The reason for this approach was (1) the time interval between the roentgen examination and the delivery was over one week in 52 cases and often several months with the smaller fetus (2) when applied in practice the birth weight will not be known at the time of examination.

The correlation between the estimated and the observed weight was 0.71 for the 78 cases with less than one week between examination and delivery. The average discrepancy between the calculated and the true weight was 288 g.

Results

The corrections of the A/V quotient that were necessary for (1) varying fetal weight and (2) angle of rotation around the long axis of the fetal body relative to the mother in normal cases were determined separately.

The average A/V ratio for groups of normal fetus within 500 g weight intervals were calculated. A compilation of these average values revealed a reduction in the quotient of 0.12 per 1000 g increase in estimated weight. This means that the lumbar vertebral length increases relative to the abdominal diameter by around 3 per cent for each 1000 g increase of fetal weight in the later stages of gestation.

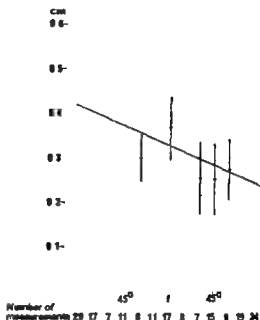


Fig. 3. Average subcutaneous fat thickness (y axis) on both sides of the abdomen with standard deviations for different angles of rotation around the long axis of the fetal body (x axis). The best linear fit to the means has been drawn.

The angle of rotation around the long axis of the fetal body would theoretically influence the A/V quotient if the cross section of the body at L1 had the form of an ellipse rather than a circle. The values of the average A/V quotient in the different groups of rotation were calculated to confirm this so as to be able to calculate the proportions between the major and the minor axes of the ellipse (Fig. 2). The values varied but suggested the elliptical form. The proportion between the axes of the ellipse giving the best least squares fit was thus determined. The following simplified formula was used:

$$R = a \sqrt{(\tan v + 1)/(\tan v + a)}$$

in which R is the elliptic radius at an angle v to the minor axis and a is the proportions between the major and the minor axis of the ellipse. The formula provides a good approximation of the exact value when a is close to 1. The resulting curve with $a = 1.084$ had the best least squares fit (Fig. 2). As no variation in lumbar vertebral length with the angle of rotation was evident this means that the average transverse abdominal diameter of the fetus is 1.084 times more than the sagittal diameter.

The thickness of each of the two layers of abdominal subcutaneous fat was related to the angle of rotation around the long axis of the fetal body (Fig. 3). The fat layer increases approximately linearly from the back to the umbilical line.

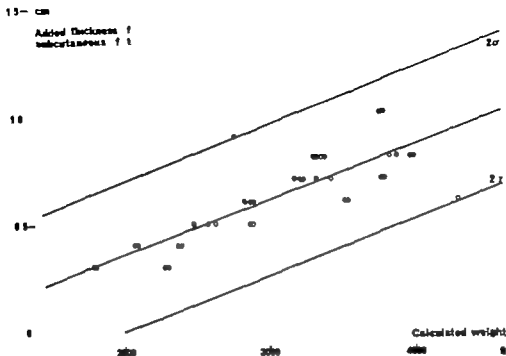


Fig. 4 The added thickness of subcutaneous fat plotted against calculated weight for 93 normal fetuses. Regression line and $\pm 2\sigma$ sigma limits have been drawn.

The correlation coefficient of the means is -0.82 . Thus the sum of the two measurable subcutaneous fat layers at the level of the first lumbar vertebra (L1) is fairly constant and independent of the individual angle of rotation. The best value of subcutaneous fat thickness from the practical and theoretical points of view is thus the sum of the fat layers on each side of the fetal body obtained tangentially. This added thickness was plotted against the calculated fetal weight and the 93 healthy cases in which the fat tissue could be measured on both sides of the abdomen were included. The correlation coefficient is 0.71 and the mean deviation from the regression line for the average estimated weight 0.17 cm.

Twenty four of the 36 fetus of diabetic mothers each had an A/V quotient below the average normal value corrected for the above mentioned factors: the mean deviation was -0.05 . One falling outside and over the two sigma limits. Three of the 28 fetus of diabetic mothers in which the subcutaneous fat could be measured on both sides of the abdomen were outside the two sigma limits of the normal group (Fig. 4). The distribution of the diabetic cases relative to these

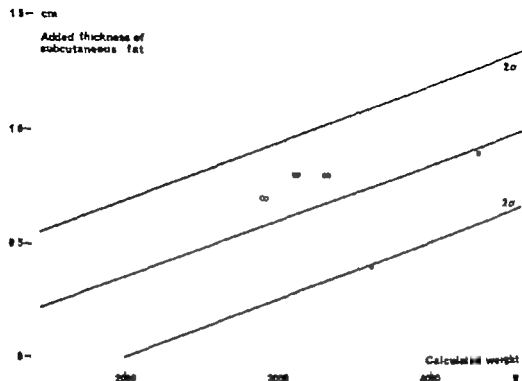


Fig. 5 The added thickness of subcutaneous fat plotted against calculated weight for 73 fetuses of diabetic mothers. Regression line and \pm two sigma limits from the plot of the normal cases in Fig. 4.

two sigma limits appears in Fig. 5. A statistical analysis of the two materials of the added subcutaneous fat relative to the assessed fetal weight indicated no differences in the distribution.

Discussion

The intention of this work was to find out if any differences might exist between fetuses of normal and diabetic mothers in abdominal dimensions and the thickness of the subcutaneous fat. The measurements were carried out in roentgenograms of the fetus. This may introduce several foreseeable errors including a varying enlargement factor and position of the fetus. Corrections for the influence of varying fetal weight and rotation in the uterus on the abdominal dimensions assessed were established to reduce these errors as much as possible. The corrections were based on descriptive statistical methods and no analyses of significance were made. The values are, however, in part confirmed by a recalculated

lation of figures given by SCALMON & CALKINS (1929). These authors published average sagittal and transverse body diameters measured at autopsy at the levels of the tenth rib and the umbilicus for 53 and 51 fetus respectively with a body length exceeding 40 cm. Recalculation of these diameters indicates that the average fetus was 1.082 times broader in the transverse than in the sagittal direction. The value of 1.084 obtained in the present roentgen examinations was thus strengthened.

Neonates of diabetic mothers present with a higher average weight than normal newborns (Hsia & Gellis 1957) as previously stated. No obvious difference appears however to exist between these groups as regards the thickness of the subcutaneous fat or the quotient between abdominal diameter and lumbar vertebral length. One possible explanation is that the diabetic mothers were so carefully controlled and received such exact therapy that a possible effect of the diabetes on the fetal abdominal dimensions and the thickness of the subcutaneous fat was suppressed and thus not possible to detect by the technique of examination (Møller 1970). Russel & Range (1969) have stated that a considerable acceleration of fetal skeletal growth occurs in fetus of diabetic mothers treated with drugs. The conclusion is that these fetus have a higher birth weight because of accelerated growth although they preserve abdominal proportions and thickness of subcutaneous fat in relation to body weight. This means that it will not be possible by roentgen examination to assess the potential influence of maternal diabetes on the fetus from the determination of abdominal dimensions or subcutaneous fat. A comparison between fetal maturity or weight and menstrual estimation of the length of pregnancy would appear to be the only means of determination. The thickness of the subcutaneous fat expressed as the sum of the appropriate layers on both sides of the abdomen at the level of L1 constitutes a significant positive correlation to estimated fetal weight. This would appear to be a useful quantification of a qualitative concept that has long been in use. The standard deviation of the normal values is however too large to permit the added thickness of the subcutaneous fat to remain more than a complement to other factors used in assessment of fetal maturity.

Theoretically the factors may be influenced by abnormalities other than maternal diabetes. Dysmaturity comes to mind but an examination of its significance has not been made.

SUMMARY

Assessment of the abdominal diameter, length of the lumbar vertebra and the thickness of the subcutaneous fat revealed no obvious differences between the fetus of normal and diabetic mothers. It is concluded that the accelerated fetal growth and higher birth weight

of diabetic fetuses are not normally accompanied by altered abdominal proportions or fat layer thickness. The added subcutaneous fat at the level of the first lumbar vertebra constitutes however a valuable means of determining fetal maturity.

ZUSAMMENFASSUNG

Eine Abschätzung des abdominalen Diameters, der Länge der Lumbalwirbelsäule und der Dicke des subkutanen Fettgewebes ergab keine klaren Unterschiede zwischen den Foeten normaler und diabetischer Mütter. Es wird daraus gefolgert, dass der raschere fötale Zuwachs und das höhere Geburtsgewicht des diabetischen Fetus normalerweise nicht von veränderten abdominalen Proportionen oder Änderungen in der Dicke des Fettlagers begleitet wird. Die Dicke des subkutanen Fettgehaltes in der Höhe des ersten Lumbalwirbels bildet jedoch ein brauchbares Mass zur Bestimmung der fötalen Reife.

RÉSUMÉ

La mesure du diamètre abdominal de la longueur de la colonne lombaire et de l'épaisseur de la graisse sous-cutanée n'a pas montré de différence évidente entre les foetus de mère normale et de mère diabétique. Les auteurs concluent que l'accélération de la croissance fœtale et l'augmentation du poids de naissance des foetus de mères diabétiques sont habituellement pas accompagnées par des modifications des proportions d'abdomen ou de l'épaisseur de la couche adipeuse. L'augmentation de la graisse sous-cutanée au niveau de la première vertèbre lombaire constitue cependant un moyen intéressant pour déterminer la maturité fœtale.

REFERENCES

- EDHOLM P. A compressor for use in foetal roentgenography. *Acta radiol* 4 (1956) 40.
 HILL D. Y. Y. and GRILLIS S. S. The birth weight in infants of diabetic mothers. *Ann Hum Genet* 22 (1957) 80.
 MÖLLER E. B. Studies in diabetic pregnancy. *Lundborg university medical dissertations* 1 (1970).
 RINGERTZ H. Method for assessment of fetal weight. *Acta radiol. Diagnosis* 11 (1971) 515.
 RUBEN J. G. B. and RANGECROFT R. G. The effect of fetal and maternal factors on adipological maturation of the fetus. *J. Obstet. Gynaec. Brit. Comm.* 76 (1969) 497.
 SCAMMON R. E. and CALKINS L. A. The development and growth of the external dimensions of the human body in the fetal period. The University of Minnesota Press, Minneapolis 1929.

ELIMINATION OF DIATRIZOATE BY PERITONEAL DIALYSIS IN RENAL FAILURE

N MILMAN and E CHRISTENSEN

High doses of contrast media containing iodine have proved to be of considerable diagnostic value for urography in renal failure (STAGE et coll 1971 1973). Normal subjects excrete diatrizoate almost exclusively by glomerular filtration (DEKKERS 1963). Impairment of renal function delays excretion and increases extrarenal elimination which takes place mainly through the liver (HANSSON & LINDHOLM 1963). STAGE et coll (1971) and MILMAN & STAGE (1974) demonstrated that high doses of diatrizoate in patients with renal failure may cause further deterioration in renal function, sometimes making rapid removal of the medium desirable. The present investigation was therefore undertaken to assess the value of peritoneal dialysis for this purpose.

Material and Methods The material comprised 3 patients with chronic renal failure with a mean 24 hour endogenous creatinine clearance of 3.7 ml/min (Table 1). None of the patients had any history of peritonitis, intra abdominal surgery or hepatic disease. Peritoneal dialysis was performed through a plastic catheter placed in the sacral fossa using the intermittent flow technique with an approximate cycle length of one hour (inflow 10 minutes, diffusion time 30

Submitted for publication 8 August 1973

Table 1

Data of patients and peritoneal dialyses bef d = before dialysis aft d = after dialysis chron /yel = chronic pyelonephritis chron glom = chronic glomerulonephritis

Case	Sex	Age (yrs)	Diagnosis	Endogenous creatinine clearance (ml/min)	Serum urea (mmol/l)		Serum creatinine (mmol/l)		Tonality of dialysis fluid	Total excess outflow of dialysis fluid (outflow - inflow) (l)
					bef d	aft d	bef d	aft d		

1	F	38	Chron pyel	8.5	21	10	0.70	0.44	isotonic	3.0
2	F	50	Chron glom	0.5	49	18	1.23	0.61	isotonic	2.4
3	M	22	Chron glom	3.8	34	21	1.72	1.39	isotonic	2.3
4	M	36	Chron glom	3.0	13	8	1.38	0.95	hypertonic	3.3
5	M	26	Chron glom	2.8	28	15	0.94	0.62	hypertonic	4.4

Table 2

Peritoneal clearance and plasma T₁ for diazepam before and during dialysis

Case	T ₁ for plasma diazepam (hours)		U/P ratio for diazepam	V (ml/min)	Peritoneal clearance for diazepam (ml/min)	Diazepam concentration in dial fluid as percentage of plasma at t after 2 l is diffused
	before dialysis	during dialysis				
1	23 1/2	9	0.29	47025/1370	10.3	69
2	62 3/4	15 3/4	0.28	42360/1200	9.9	73
3	46 1/4	15 1/2	0.23	38275/1105	8.7	
4	37 3/4	15 1/4	0.33	43325/1210	11.8	
5		13 1/4	0.32	48375/1570	1.8	71
	$\bar{x} = 47.1^{\circ}$	$\bar{x} = 12.1^{\circ}$			$\bar{x} = 10.7 \pm 1.6$	

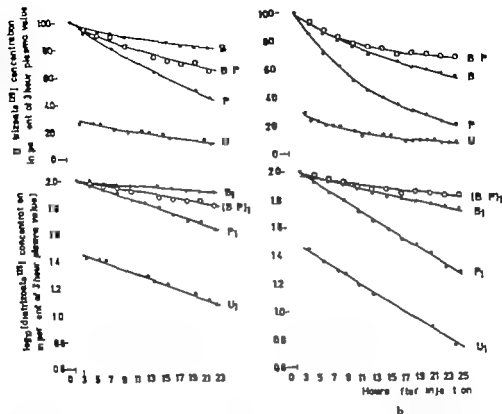
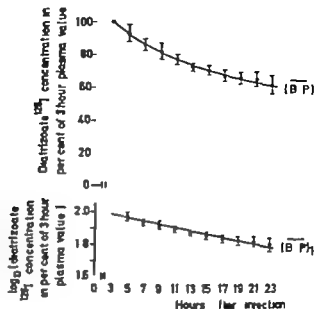


Fig 1 a) Case 2 b) Case 1 Concentration of diatrizoate in plasma and dialysate outflow B = plasma concentration before dialysis P = plasma concentration during dialysis B-P = $(100 - (B - P))$ = effect of dialysis on plasma concentration U = concentration in dialysate outflow B P₁ (B-P)₁ and U represent the corresponding curves in semilogarithmic co-ordinate system

minutes outflow 20 minutes) and a per cycle inflow of 2 l iso- or hypertonic dialysate at body temperature (Table 1). In 4 patients elimination of the diatrizoate was measured both before and during dialysis, and in one patient during the procedure.

All patients received 20 μ Ci 125 I labelled sodium diatrizoate intravenously in sodium and methylglucamine diatrizoate 76% (Urografin 76%) 1 ml/kg body weight as carrier. Blood samples were drawn before the injection at 15 minutes, 30 minutes, 1 hour and then every second hour for the next 20 to 25 hours. One ml of plasma was examined in 10 minutes in a well type scintillation counter so that the diatrizoate concentration could be measured. Peritoneal

Fig. 2 The effect of peritoneal dialysis per se on the elimination of diazotazoate represented by the fall in the concentration of plasma diazotazoate (mean of curve (B-P) in 4 patients ± 1 SD)



dialysis was started one hour after the administration of the medium the volume of each dialysate outflow was measured and the diazotazoate concentration determined by examining 4 ml in 10 minutes. Three hours after the injection of the diazotazoate, diffusion equilibrium in the extracellular space had taken place and the plasma concentration started to decline exponentially. To allow comparison between the different series the plasma diazotazoate concentration for the 3 hour sample was always taken as a unit and the other values were expressed as percentages of this value.

Peritoneal clearances of diazotazoate were calculated according to van Slyke's formula $Cl = \frac{U \times V}{P}$ in which Cl = clearance in ml/min, U = concentration

in dialysate outflow, P = plasma concentration, and V = dialysate outflow in ml/min. Peritoneal diffusion curves of diazotazoate were obtained in 3 patients by the BOEN method (1961). Blood samples were drawn at the beginning, the middle and the end of the 120 minute long diffusion period while samples of peritoneal fluid were collected every tenth minute and the diazotazoate concentration measured.

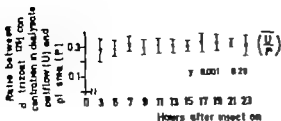


Fig. 3 Mean U/P ratio for diatrizoate during dialysis in 5 patients ± 1 SD

Results

The effect of peritoneal dialysis on the plasma half life ($T_{1/2}$) of diatrizoate appears in Table 2. Dialysis reduces the mean $T_{1/2}$ from 47 1/2 to 12 1/2 hours. Fig. 1 demonstrates changes in plasma diatrizoate concentration before (curve B) and during dialysis (curve P) together with the concentration in dialysate outflow (curve U) in Cases 1 and 2. The effect of dialysis on the elimination of diatrizoate is depicted by subtraction of the plasma concentration curve during dialysis from the plasma concentration curve before dialysis (curve B-P) calculated as $100 - (B - P)$. B_1 , P_1 , $(B - P)_1$ and U_1 are the corresponding curves in a semilogarithmic co-ordinate system. The mean B-P curve in 4 patients (curve $\overline{(B - P)}$) appears in Fig. 2 in a semilogarithmic co-ordinate system plasma concentration falls in a straight line indicating that the elimination of diatrizoate is a first order reaction, compatible with transport by diffusion. The ratio between the diatrizoate concentration in the dialysate outflow and plasma (U/P ratio) was constant in each patient throughout dialysis (Table 2, Fig. 3).

The peritoneal clearance for diatrizoate appears in Table 2: the mean peritoneal clearance was 10.7 ± 1.6 ml/min at a dialyzing rate of 2 l per hour.

Fig. 4 depicts diffusion curves (curve E) in Cases 1 and 2. After 120 minutes diffusion the concentration of diatrizoate in the peritoneal fluid was 63 to 71 per cent of the plasma concentration (Table 2).

In a semilogarithmic co-ordinate system the difference in diatrizoate concentration between the plasma and peritoneal fluids (curve $(D - E)_1$) falls in a straight line compatible with transport by diffusion.

Discussion

The peritoneal cavity is lined by a semipermeable membrane with an area of about 2.2 m² water and its solutes are transported across this membrane mainly by diffusion. The permeability of the peritoneal membrane is increased by heat, hypertonic solutions and infection (Duvvula 1971). The rate of diffusion

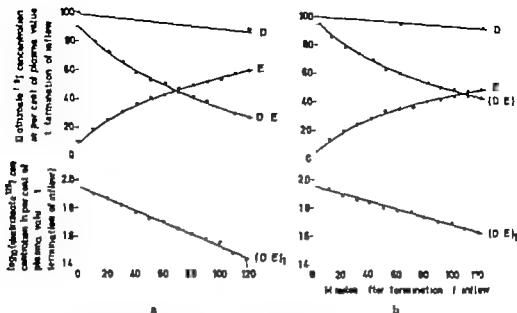


Fig. 4 a) Case 1 b) Case 2 Diffusion curves for diatrizoate D = plasma concentration of diatrizoate; E = concentration of diatrizoate in peritoneal fluid; D-E = difference between concentration of diatrizoate in plasma and peritoneal fluid (D-E); $\log_{10} D-E$ run as semilogarithmic co-ordinate system.

across the peritoneal membrane for a given substance depends, among other factors, on the size of the molecule and the degree and strength of binding to plasma proteins. According to LASSER *et al.* (1962) the protein binding of diatrizoate is negligible and the substance may for practical purposes be considered as freely diffusible.

BAILMANN *et al.* (1970) investigated the elimination of diatrizoate by peritoneal dialysis in 11 patients, by measuring the changes in the serum iodine. The patients underwent peritoneal dialysis for 44 to 67 hours with 88–143 l of dialysate. Serum iodine fell significantly in all dialyses. Sixty one and 12 per cent of the dose were recovered in the dialysate and urine respectively. The T_{1/2} and peritoneal clearance for the contrast medium were not estimated.

Diatrizoate is easily removed by haemodialysis, the T_{1/2} being about 4 hours (HANSSON & LINDBOLM 1963 and BAILMANN & KRUSKEMPFER 1973). The present results indicate that passive diffusion of diatrizoate is the most likely way of transport across the peritoneal membrane; evidence of an active transport mechanism was absent. BOEN demonstrated that the peritoneal clearance rises with an increasing dialyzing rate and that the clearances of urea and creatinine were about 22 ml/min and 13 ml/min respectively at a dialyzing rate of 2 l

per hour. The peritoneal clearance of diatrizoate in the present material appeared to be within the same order of magnitude as that of the creatinine. The high clearances in Cases 4 and 5 may probably be explained by the employment of hypertonic dialysate. BOEN reported that diffusion equilibrium between plasma and peritoneal fluid for urea was reached by 120 minutes. The mean concentration of diatrizoate in the peritoneal fluid in the present material was 68 per cent of the plasma concentration indicating that the diffusion rate of diatrizoate across the peritoneal membrane is slow compared to urea.

The extrarenal excretion of diatrizoate through the liver and small bowel epithelium in subjects with normal renal function amounts to about 2 per cent of the dose given. Decreasing renal function causes increasing extrarenal excretion which in anuric patients may be as high as 50 per cent within 3 days after the administration of diatrizoate (VAN WAAS 1972). DEVEBERG recorded a normal rapid rate of excretion with a plasma $T_{1/2}$ for diatrizoate of less than 2 hours. Impaired renal function raises the $T_{1/2}$ (VAN WAAS) as confirmed by the present results.

Some authors (STAGE et coll 1971 and MILMAN & STAGE) have demonstrated what they believed to be a nephrotoxic effect of diatrizoate. However this assumption has not yet received experimental support (BERG et coll 1958, LINDGREN 1961). BERLYNE & BERLYNE (1962) suggested that it is possible that prolonged high concentration of the contrast medium, a situation occurring in patients with renal and hepatorenal failure, might be responsible for further renal injury. Considering the general efficiency of peritoneal dialysis the elimination rate of diatrizoate is acceptable from a clinical point of view, the peritoneal clearance being within the same order of magnitude as that for creatinine. Thus hepatorenal failure no longer seems to be a contraindication for the administration of high doses of contrast medium, provided facilities for dialysis are available. If a rapid elimination of diatrizoate is indicated haemodialysis is clearly superior to peritoneal dialysis.

SUMMARY

The elimination of diatrizoate by peritoneal dialysis was investigated in 5 patients with chronic renal failure in 4 of these before dialysis as well. The method is a reliable although rather slow one of removing diatrizoate. Haemodialysis is to be preferred if rapid elimination is indicated.

ZUSAMMENFASSUNG

An fünf Fällen von Niereninsuffizienz wurde die Ausscheidung von Diatrizoat mittels peritonealer Dialyse untersucht in vier Fällen auch vor der Dialysebehandlung. Die Method ist obwohl langsam zuverlässig. Die Hämodialyse ist vorzuziehen, wenn schnelle Elimination erforderlich ist.

RÉSUMÉ

L'élimination du diatrizoate par dialyse péritonéale a été étudiée chez 5 malades atteints d'insuffisance rénale chronique. Chez 4 d'entre eux elle avait été étudiée aussi avant dialyse. Cette méthode est efficace bien que plutôt lente pour éliminer le diatrizoate. Il faut préférer l'hémodialyse si l'élimination du diatrizoate doit être rapide.

REFERENCES

- BAHLMANN J, KLUGE R and KRECKEMPER H L. Elimination von jodhaltigen Kontrastmitteln während der Peritonealdialyse bei akutem und chronischen Nierenversagen. *Z ges exp Med* 152 (1970) 323
- and KRECKEMPER H L. Elimination of iodine containing contrast media by haemodialysis. *Nephron* 10 (1973) 250
- BERG N O, LÖNNER H and WESTERBERG B. Investigation of the tolerance of the rabbit kidney to newer contrast media in renal angiography. *Acta radiol* 50 (1958) 286
- BERLYNKE N and BERLYNKE G M. Acute renal failure following intravenous pyelography with Hypaque. *Acta med scand* 171 (1962) 99
- BOYD S T. Kinetics of peritoneal dialysis. *Medicine (Baltimore)* 40 (1961) 243
- DESSERBERG T. Clinical studies on kidney function with radioactive sodium diatrizoate (Hypaque (R)). *Acta med scand* (1963) Suppl No 442
- DUNEA G. Peritoneal dialysis and hemodialysis. *Med Clin N Amer* 55 (1971) 153
- HANSSON R and LINDHOLM T. Elimination of Hypaque (Sodium 3,5-diacetamido-2,4,6-triodobenzoate) and the effect of haemodialysis in anuria. A clinical study and an experimental investigation on rabbits. *Acta med scand* 14 (1963) 611
- LAMER E C, FAIR R S, FUJIMAGARI T and TRIPP W N. The significance of protein binding of contrast media in roentgen diagnosis. *Amer J Roentgenol* 87 (1962) 338
- LINDQVIST P. Renal circulatory insufficiency after renal angiography. *Acta radiol* 56 (1961) 423
- MILMAN N and STAGE P. High-dose urography in advanced renal failure. II. Influence on renal and hepatic function. *Acta radiol Diagnosis* 15 (1974) 104
- STAGE P, BIRK E, FOLKE A. and KARL A. Urography in renal failure. *Acta radiol Diagnosis* 11 (1971) 357
- MILMAN N and BIRK E. High-dose urography in advanced renal failure. I. Evaluation of diagnostic value. *Acta radiol Diagnosis* 14 (1973) 689
- AN WAKS P. High dose urography in oliguric and anuric patients. *Excerpta Medica Foundation Amsterdam* 1972

FROM THE DIVISION OF PHARMACOLOGY (DIRECTOR PROF P LINDGREN) DEPARTMENT OF DRUGS NATIONAL BOARD OF HEALTH AND WELFARE, 104 01 STOCKHOLM AND THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF O F SALTZMAN) UMEÅ UNIVERSITY 901 85 UMEÅ SWEDEN

INCREASE OF SUBCAPSULAR RENAL PRESSURE AFTER INTRAVENOUS IODIPAMIDE AND OTHER PARENTERAL CONTRAST MEDIA

An experimental investigation

P LINDGREN and G F SALTZMAN

Renal damage due to intra arterial injection of contrast media was a problem to be reckoned with in the roentgen diagnostic work during the late 40s and 50s. The difficulties were especially apparent in the period when sodium acetrizate (Urokon Triurol and others) was the dominating medium for angiography. The introduction of sodium diatrizoate for this examination radically reduced the clinical renal complications. After BERG *et coll* (1958) and LINDGREN (1961) had demonstrated experimentally the marked difference between the acetrizate and diatrizoate preparations, as regards renal toxicity, renal complications in connection with intra arterial injections ceased to be serious.

The armamentarium of contrast media still contains a medium with largely the same toxicity as the acetrizate preparations, namely iodipamide (Biligradin, Cholegrafin) for intravenous cholegraphy. The introduction of iohexamide

Submitted for publication 14 March 1973

(Bilivistan) as a contrast medium for cholangiography has failed to bring about any radical change in this respect, despite its lower toxicity. Iodipamide is not, it is true, injected intra arterially but LINDÖREN *et coll.* (1966) have demonstrated that its intravenous injection may cause renal damage observable in both experimental and clinical roentgenographic examinations. ALWALL *et coll.* (1955) suggested that the intravenous injection of the now largely abandoned diiodized contrast media could contribute to the development of renal insufficiency.

BEAC *et coll.* and LINDÖREN observed enlarged and edematous kidneys after intra arterial injections of sodium acetrizoate. LINDÖREN also demonstrated that the circulation through the kidneys was considerably reduced when sodium acetrizoate was injected intra arterially. Similar changes were reported by LINDÖREN *et coll.* (1966) after intra arterial injections of iodipamide. Diatrizoate preparations also according to APERIA *et coll.* (1968) have a slowing effect on the circulation when administered intra arterially.

All the contrast media for parenteral administration cause as a rule after intra arterial injection varying degrees of peripheral vascular dilatation with attendant increase in the peripheral circulation. The kidneys thus seem to constitute an exception to an otherwise generally valid rule.

LINDÖREN *et coll.* (1966) demonstrated that intravenous iodipamide injections also caused renal edema in an experimental material as well as renal enlargement in a clinical series of cholangiographies. The renal parenchyma is covered with a fairly inelastic capsule. The fact that it was possible despite this inelasticity to observe a distinct renal swelling, prompted an investigation into the extent to which subcapsular pressure increase could be measured after an intravenous injection of iodipamide and furthermore whether this increase was such that it could explain the paradoxical decrease in the renal circulation.

Material and Methods The effect of intravenous injections of clinical doses of contrast medium was investigated in 13 cats anesthetized with pentobarbital sodium intraperitoneally (30 mg/kg). supplementary amounts were administered when necessary during the experiment, a tracheal cannula was inserted to facilitate respiration. The systemic blood pressure was measured in the left carotid artery which was cannulated and connected to an electromanometer (Siatham P23AA). The recordings were made with a conventional polygraph Grass model 5.

The left kidney was exposed through an incision in the 6th flank under the 1st rib. A cut 3 to 4 mm long was made in the renal capsule approximately at the middle of the ventral aspect of the kidney. Care was taken to prevent bleeding and damage to the renal surface. Lithene was used to prevent infection. A thin rubber bladder attached to the cut end of the capsule was crumpled and placed over the incision.

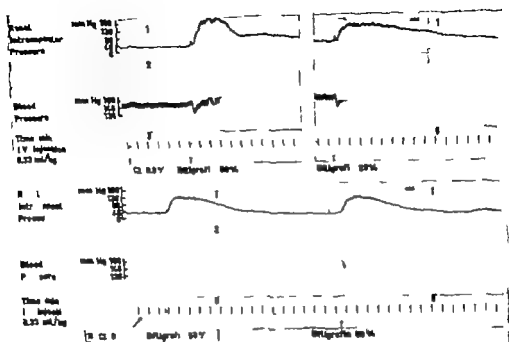


Fig 1 Cat 5 kg. Changes in blood pressure and renal subcapsular pressure after intravenous injection of 0.53 ml/kg Bili-vulin forte. The increases in subcapsular pressure were exceptionally high.

tween the capsule and the surface of the kidney. The tip of the catheter inside the bladder had a number of small holes so that the communication between the bladder membrane and the catheter would remain open even if the tip happened to come into contact with the bladder wall at any point. The filling of the catheter and bladder with physiologic saline was made with great care to ensure that all air was eliminated. The volume of saline in the bladder usually 0.05 to 0.1 ml was adjusted to keep the bladder wall completely slack so that they would not affect the pressure conditions through autotension. The other end of the catheter was attached to a sensitive electromanometer (Statham P23BB). As the walls of the catheter could be considered as almost totally unyielding at the pressures under investigation the method implied that a completely closed fluid system had been produced in which the renal subcapsular pressure was transmitted to the electromanometer. Only small volume variations thus occurred in the pressure receiving bladder with little liquid displacement in the system (displacement in the electromanometer 12 ml per 100 mm Hg). The recordings were made with the same polygraph as was used for the blood pressure measurements.

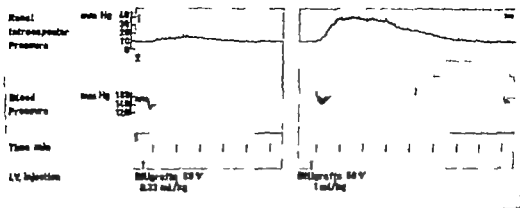


Fig. 2. Cat 3.0 kg. Changes in blood pressure and renal subcapsular pressure after intravenous injection of Bilgrafen forte in two different doses.

The following contrast media were given intravenously through a plastic catheter inserted in the cephalic vein in a foreleg: Bilgrafen forte 50 % (Schering) (methylglucamine iodipamide); Triurol 50 % (Leo) (sodium acetrizate); Urografin 60 % (Schering) (sodium and methylglucamine diatrizoate).

Results

Effect of Bilgrafen forte. The blood pressure fall after a rapid intravenous injection of Bilgrafen forte observed in earlier investigations was confirmed and was often considerable (Figs 1-3). The first injections in these experiments 0.33 ml/kg in both instances resulted in a fall of 30 and 50 mm Hg respectively.

The initial values for the renal subcapsular pressure varied considerably in the different cats, usually lying between 10 and 30 mm Hg. A control dose of physiologic NaCl intravenously in all the experiments produced no appreciable reaction. Bilgrafen forte on the other hand in a dose of 0.33 ml/kg usually produced a marked increase in pressure. An experiment in which exceptionally high subcapsular pressures were recorded is illustrated in Fig. 1. After 10 to 15 seconds, in other words the same latency period as for the fall in blood pressure, a small initial rise in the subcapsular pressure was observed. This subsided within about ten seconds but was followed by a second, steep rise which in the experiment illustrated in Fig. 1 had within 15 minutes raised the renal subcapsular pressure to that of the arterial blood. After a few minutes the subcapsular pressure fell again although only to a level corresponding approximately to twice the initial level (60 to 70 mm Hg as against roughly 30 mm Hg). Nearly 1.5 hours elapsed before it had returned more or less to the initial level. An earlier investiga-

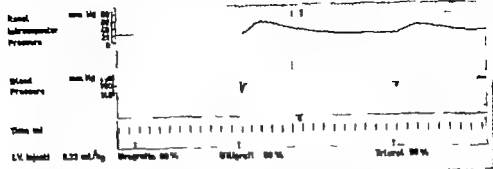


Fig 3 Cat 3.3 kg. Changes in blood pressure and renal subcapsular pressure after intravenous injections of contrast media of 0.33 ml/kg. Comparison between Urografin, Bilagrafin forte and Triolol.

tions have indicated that the circulatory effects following the intravenous injection of Bilagrafin forte display marked tachyphylaxis (BRISMAN *et al.* 1971) it was considered of interest to repeat injections of the same dose. Three such injections were given at intervals of 15 to 20 minutes, the interval between the first and second injections being 1.5 hours (Fig 1). The reaction to these injections was similar, although the increase in the subcapsular pressure was slightly lower compared to its rise following the first injection; the tachyphylaxis was not so marked, however, as it was for the blood pressure fall—the fourth injection caused virtually no fall at all.

It should however be pointed out that while the quantitative variations between the different animals were considerable, some degree of increase in the subcapsular pressure occurred in all of them. One cat displayed inconsiderable reaction to 0.33 ml/kg Bilagrafin forte (Fig 2). The fall in blood pressure was of the usual magnitude, indicating that the blood pressure reaction and the change in the subcapsular pressure were not correlated quantitatively. When the dose was increased—to 1 ml/kg in the experiment (Fig 2)—a more marked rise in the subcapsular pressure however occurred.

As a considerable difference has been observed in the circulatory effects as well as in the renal enlargement in the groups between rapid and slow intravenous injection of Bilagrafin, a few experiments with slow injection of the contrast medium (over 5 min) were also run. No changes were observed in the renal subcapsular pressure or in the arterial blood pressure.

Effects of other contrast media. The difficulty of quantitatively evaluating the reactions if several injections were made, and if different contrast media were used for them soon became obvious. A few experiments were made nevertheless to gain further information. Fig 3 illustrates the result obtained in one of

them in which a small dose, 0.33 ml/kg of three different contrast media, Urografin Biligrafin forte, and Triurol, were given intravenously in turn. Urografin produced an inconsiderable rise in the subcapsular pressure, while Biligrafin forte and Triurol caused appreciable reactions both as regards a fall in blood pressure and an increase in the renal subcapsular pressure.

Discussion

Considering the comprehensive literature on renal injury after intravenous and intra-arterial injections of contrast media for urographic and angiographic examinations it would not be surprising to find that other media with the same form of administration could produce similar effects. The bile duct contrast medium Biligrafin forte was therefore subjected some years ago to an investigation (LINDÖREN *et coll.*) it was then observed that an intravenous injection of Biligrafin forte produced a marked decrease in the renal circulation in cats. Histologic examination revealed exceptionally severe edema in the renal parenchyma with considerable dilatation of the glomerular capsules and the tubules. Transient renal enlargement was demonstrated furthermore, in cases that had undergone routine cholegraphies with Biligrafin forte given intravenously by rapid injection.

It was these observations that motivated the present investigation which was undertaken mainly to obtain an objective method of measurement for a parameter—renal subcapsular pressure—that would be closely correlated with renal enlargement. The results provide ample support for the view advanced earlier, namely that Biligrafin forte, even in clinical doses, may have a deleterious effect on the kidneys.

It was interesting to observe the time relations between a subcapsular pressure rise and changes in the renal blood flow (cf. LINDÖREN *et coll.* 1966, fig. 4). The rise in the subcapsular pressure set in after about 30 seconds, and the decrease in the circulation had a latency period of 40 to 50 seconds. This strongly supports the previously expressed view that any decrease occurring in the blood flow after injection of a contrast medium with a circulatory action, such as of the iodipamide and acetazotate types, should not be interpreted as active vasoconstriction but rather as being due to other factors (LINDÖREN 1961, LINDÖREN *et coll.* 1966). The reaction might first well be explained as a vasoparalytic effect heightened by a strong element of disturbed permeability with edematous renal swelling, increased subcapsular and intrarenal pressures, and a consequent retardation of the circulation. Secondly, there could be tissue hypoxia which in its turn increases the effects. The physiologic relation between factors such as renal circulation and intrarenal pressure have been examined in detail by ÅSTRÖM *et coll.* (1962) and ÅSTRÖM & SAMELIUS (1962). A contributory cause of the

changes might be the intravascular erythrocyte aggregation produced by Biligradin forte (LINDGREN et coll 1964)

In view of the rapidity with which the rise in the subcapsular pressure took place, the disturbed permeability of the renal vessel walls ought probably to have been considerable. That roentgenographic contrast media may cause disturbance in vascular permeability is recognized in the literature. BROMAN & OLSSON (1956) for instance in a series of papers reported damage to the blood-brain barrier in connection with experimental carotid angiographies. The increase in intracranial pressure described by KASTROM & LINDGREN (1960) was interpreted as another indication of disturbed permeability.

It also seems worth drawing attention to the great individual variations in the observed reactions from the quantitative aspect. Only in about one case were there pressure rises that could be described as being so high that they could reasonably have given rise to functional disturbances. No conclusions as to the causes of the variations can be drawn from the present material: there seems to be good agreement with clinical observations (LINDGREN et coll 1966). In that material too considerable variations from case to case were observed with respect to the kidney enlargement recorded. Although the renal changes reported cannot be disregarded and although the fact remains that among the contrast media in general use Biligradin forte seems to be the one with the highest toxicity, the clinical risks should not be exaggerated and transient edema in the renal parenchyma in all probability and in most cases passes unnoticed. Support for this view arises in the fact that apart from the kidney enlargement mentioned signs of renal damage in connection with choleographies have not been noticed in clinical practice.

Acknowledgements

This investigation was supported by the Swedish Medical Research Council (grant No B 67 14 707701)

SUMMARY

A simple method for recording the renal subcapsular pressure in cats is described. Considerable increases in the pressure were observed after the intravenous injection of clinical doses of Biligradin forte. Their clinical significance and their relation to the changes after Biligradin described earlier such as renal enlargement, retardation of the renal circulation and the formation of edema are briefly discussed.

ZUSAMMENFASSUNG

Es wird eine einfache Methode zur Registrierung des subkapsulären renalen Drucks bei Katzen beschrieben. Ein erheblicher Anstieg des Drucks wurde nach intravenöser Injektion von klinischen Dosen von Biligradin forte gefunden. Die klinische Bedeutung und deren

them, in which a small dose, 0.33 ml/kg of three different contrast media Urografin, Biligrafin forte, and Triurol, were given intravenously in turn. Urografin produced an inconsiderable rise in the subcapsular pressure, while Biligrafin forte and Triurol caused appreciable reactions both as regards a fall in blood pressure and an increase in the renal subcapsular pressure.

Discussion

Considering the comprehensive literature on renal injury after intravenous and intra-arterial injections of contrast media for urographic and angiographic examinations, it would not be surprising to find that other media with the same form of administration could produce similar effects. The bile duct contrast medium Biligrafin forte was therefore subjected some years ago to an investigation (LINDGREN *et coll.*) it was then observed that an intravenous injection of Biligrafin forte produced a marked decrease in the renal circulation in cats. Histologic examination revealed exceptionally severe edema in the renal parenchyma with considerable dilatation of the glomerular capsules and the tubules. Transient renal enlargement was demonstrated furthermore, in cases that had undergone routine cholangiographies with Biligrafin forte given intravenously by rapid injection.

It was these observations that motivated the present investigation which was undertaken mainly to obtain an objective method of measurement for a parameter—renal subcapsular pressure—that would be closely correlated with renal enlargement. The results provide ample support for the view advanced earlier, namely that Biligrafin forte even in clinical doses may have a deleterious effect on the kidneys.

It was interesting to observe the time relations between a subcapsular pressure rise and changes in the renal blood flow (cf. LINDGREN *et coll.* 1966, I, 4). The rise in the subcapsular pressure set in after about 30 seconds and the decrease in the circulation had a latency period of 40 to 50 seconds. This strongly supports the previously expressed view that any decrease occurring in the blood flow after injection of a contrast medium with a circulatory action such as of the iodipamide and acetrizolate types should not be interpreted as active vasoconstriction but rather as being due to other factors (LINDGREN 1961, LINDGREN *et coll.* 1966). The reaction might first well be explained as a vasoparalytic effect heightened by a strong element of disturbed permeability with edema, renal swelling, increased subcapsular and intrarenal pressures and a consequent retardation of the circulation. Secondly, there could be tissue hypoxia which in its turn increases the effects. The physiologic relation between factors such as renal circulation and intrarenal pressure have been examined in detail by ÅSTRÖM *et coll.* (1962) and ÅSTRÖM & SAMELILÄ (1962). A contributory cause of the

ANAL FISTULOGRAPHY

S AHLBACK, B HOLMSTRÖM and B SYL

Anal fistulography has seldom been described and appears to have been little used: the latter has probably been due to the difficulty in defining the relationship between the fistula and the anal canal. A special technique has therefore been employed to demonstrate the latter and the radiologic results have been related to clinical observations.

Technique A Clausen rectal catheter with a balloon and a solid rubber ball delineates the anal canal (Fig. 1). The balloon is inflated within the rectum so that the ball is pressed against the anus and the anal canal is defined in between. The ball has a diameter fixed at 35 mm which makes it possible to correct the magnification in the roentgenograms for exact measurements. Urografin 60 % is injected during fluoroscopy through a Nelaton catheter wide enough to occlude the external opening of the fistula: a lead marker having previously been applied to the external opening. Full-size films are taken in frontal, lateral and oblique projections.

Material This consisted of 98 fistulographies in 93 patients selected since they had been referred for special treatment: most of the patients had been treated earlier at other hospitals.



Fig 1 Claussen rectal catheter (in situ to the right). The catheter delineates the anus. Lead marker at external opening of the fistula.

Anatomy and terminology. The relationship between the fistula and the sphincter muscles is of considerable practical importance since the treatment in principle consists of establishing a wide communication of the fistula with the anal canal. The partial severance of the sphincters must be performed with care for if too great it may produce incontinence (Fig 2).

The fistulas are classified clinically as low, high and perirectal. The boundary between low and high anal fistulas is the dentate line; this is also called the

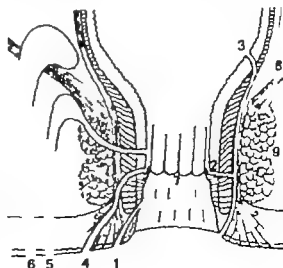


Fig 2 Relationship of various types of anal fistulas to the sphincter muscles: (1) subcutaneous fistula (2) intermuscular low fistula (3) intermuscular high fistula (4) low anal fistula (5) high anal fistula (6) perirectal fistula. Anatomic structures: (7) dentate line (8) puborectalis muscle (9) anal sphincter. (Published by courtesy of Ellis and Acta chirurgica.)



Fig 3 Incomplete low anal fistula A-p Contrast filling of an recto-rectal cavity Perforation of the sphincter muscle (→) \ inner opening not contrast filling around the balloon

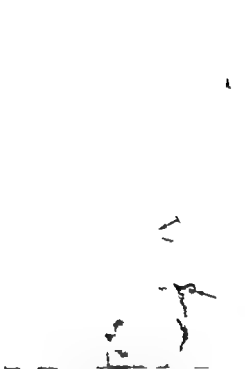
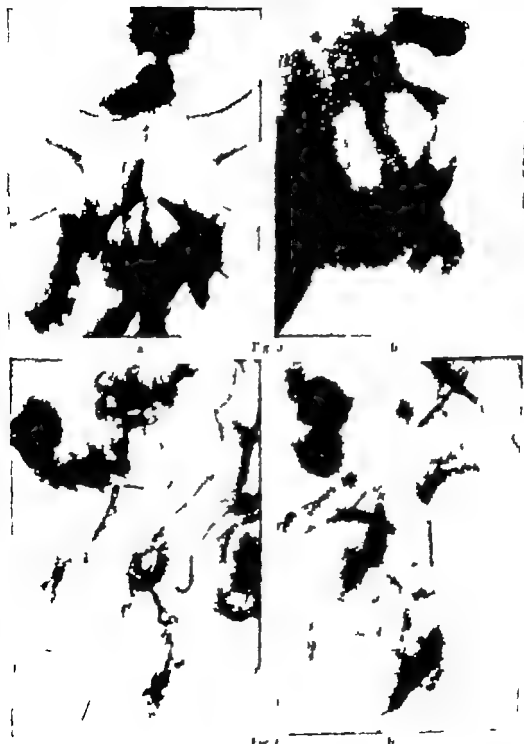


Fig 4 Complete high anal fistula Oblique projection External opening marked with lead strip (→) Inner opening (⇨) 17 mm from the anus with contrast medium around the balloon

pectinate line or the anocutaneous line and represents the junction of the zones of the anal canal lined with stratified squamous epithelium and columnar epithelium respectively. Since the dentate line is not radiographically demonstrable it was arbitrarily considered to lie 15 mm above the anus corresponding to its anatomic location. The puborectal loop constitutes the boundary between high anal and puborectal fistulas. This loop is that part of the levator ani that merges with the upper part of the sphincter; this is also not demonstrable radiographically but experience has taught that it lies about 30 mm above the anus. This correlated well with the clinical results although probably due to scar formation and deformity of the anus a slight discrepancy was sometimes observed.



(For legend see opposite page)

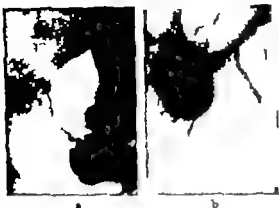


Fig 7 Complete high anal fistula. Conventional technique without marking of the anus (a). The patient was referred with diagnosis of perirectal fistula. The balloon catheter technique (b) revealed the correct diagnosis.

Forty six of the 98 fistulas were radiographically complete with an internal opening (Figs 4-5) while only a perforation of the sphincter without any filling of the anal canal was evident in a further 24 cases (Fig 3) thus in about three quarters of the material the anorectal origin of the fistulas was revealed. Two of the remaining 28 fistulas without demonstrable connection with the anorectal lumen were connected with diverticulae at a higher level in the sigmoid colon (Fig 6) while one was caused by septic spondylitis. The remainder were superficial or deep abscesses without demonstrable origin.

The radiologic findings were confirmed by operation in 67 cases. An internal opening was evident at operation however in a further 17 cases in which only a large perirectal cavity had been demonstrated. An internal opening or a sphincter perforation was apparent radiographically in 10 cases but was not verified in 7 of these this was by reason of spontaneous healing of the external opening obviating surgery. The internal opening had possibly closed between the roentgen examination and the operation in the remaining 3 cases. Detailed operation notes were not available in 4 cases.

Fig 5 Complete high anal fistula (horse-shoe fistula). a) Ap and b) lateral (sacrum to the right). These fistulae generally have the inner opening in the midline of the posterior wall. The anal canal is deformed by abscess formation.

Fig 6 Complete perirectal fistula. a) Left anterior oblique and b) lateral. Fistula horse shoe shaped like the previous one but situated anterior to the anal canal and the rectum. The patient had prostatitis. Fistulography revealed that the fistula originated from the sigmoid colon (→).

DISCUSSION

The surgical treatment of perianal fistulas demands that the internal opening be localised as the approach varies according to the level. A simple lay opening procedure is sufficient in low anal fistulas but a more complicated operation often of a plastic nature, is necessary in high fistulas. Rectal fistulas always need temporary colostomy followed later by local excision.

Experienced proctologists have denied the need for roentgen examination of anal fistulas and have trusted solely in probing. This may however be dangerous and actually is the most common cause of rectal fistulas. Fistulography is often performed without delineating the anus, so that the presence of an inner opening although not its level, may be demonstrated. If the contrast medium should enter the anus, it frequently may trickle up the rectum. The inner opening cannot then be identified and the fistula is often erroneously considered to be rectal. In point of fact more than 99 per cent are anal in origin.

Fistulography with precise delineation of the anal canal increases the possibilities of a correct diagnosis and adequate treatment. This is not to say that all perianal fistulas must be radiologically examined. If gentle easy probing can clarify the conditions a roentgen examination seems to be unnecessary. Otherwise interruption of the probing and fistulography is advisable. Fistulography should always be performed in patients with relapsing fistulas.

SUMMARY

A precise method of fistulography in fistulas of the rectum and anal canal has proved to be a valuable asset to the clinical examination increasing the scope and accuracy of radical surgery. The technique enables the relationship between the fistula and the bowel correctly to be determined.

ZUSAMMENFASSUNG

Eine exakte Methode der Fisteldarstellung am Fistel des Rektums und Analkanals erwies sich als ein brauchbarer Zusatz bei der klinischen Untersuchung und erweitert die Indikation und Genauigkeit der radikalen Chirurgie. Das Verfahren ermöglicht es die Beziehung der Fistel zum Darm genau festzustellen.

RÉSUMÉ

Une méthode précise de fistulographie pour les fistules du rectum et du canal anal s'est montrée utile pour compléter l'examen clinique. Elle étend le domaine de la chirurgie radicale et améliore sa précision. Cette technique permet de déterminer correctement les rapports entre la fistule et l'intestin.

REFERENCES

- BETTLER H J Die Fistulographie anorectaler Fisteln Fortschr Röntgenstr 99 (1963) 710
GOLDSTEIN J C Surgery of the anus rectum and colon Casecl and Comp London 1961
LILJUS G Fistula in ano Acta chir scand (1968) Suppl No 383

PERCUTANEOUS NEPHROPYELOSTOMY

L. E. ALMÖR and J. FERNSTRÖM

Percutaneous puncture of the renal pelvis with insertion of a catheter is a method of temporary supravascular diversion rarely used (GOODWIN & CASEY 1955 BARTLEY et coll 1965 VELA NAVARRETT 1971 MOLIN & ULMSTEN 1971 SATTOR 1971 JONSSON et coll 1972). This technique makes it possible to drain the upper urinary tract in bilateral total or partial ureteric obstruction. As the procedure may be carried out under local anaesthesia and furthermore is simple it may be the one of choice in cases of uremia. The method is also valuable in selected cases of permanent unilateral ureteric obstruction providing a measure of saving the function of the kidney. Since adequate function of nephrostomy largely depends on the size and position of the tube employed a new technique has been developed: this provides satisfactory drainage which may even be made permanent if so required.

Material This comprised 55 cases in 51 of which adequate function of the nephrostomy was achieved. Nephrostomy was unsatisfactory in 4 in 2 of these cases the kidneys were indurated secondary to pyelonephritis, and the special instrument could not be introduced into the pelvis. Hydronephrosis was absent in 2 cases and this prevented application of the method.

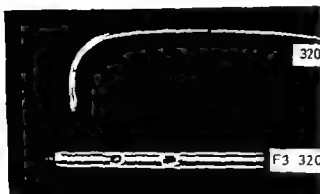


Fig 1 Instrument for percutaneous nephrostomy. Paired polythene tube 320. Tube thread on the stylet F3 + 320.

Satisfactory unilateral or bilateral nephrostomy was obtained in the 51 cases in 30 of which uremia was evident and caused by bilateral ureteric obstruction. Thirteen cases had carcinoma of the uterus or ovary, 13 carcinoma of the urinary bladder, one carcinoma of the prostate, one teratoma of the testis, one case had carcinoma of the sigmoid and one case was due to surgical intervention, there were 16 cases of metastases.

Twenty-one cases had unilateral ureteric obstruction, in 6 this was following operation and in 3 cases of carcinoma of the bladder after preoperative radiation therapy. One case of carcinoma of the sigmoid with metastases, 3 of ureteric stricture, one of malignant lymphoma and one case of schwannoma were also observed, a case of retroperitoneal fibrosis and another that had previously had right nephrectomy and had developed left ureteric calculi as well as 4 cases of carcinoma of the uterus were also included. In 13 of the 55 cases bilateral nephrostomy was performed while in the remaining cases the procedure was unilateral.

Technique The instrument used consists of a sharp-ended stylet 9 cm long and with a diameter of 2.2 mm and a polythene tube 8.5 cm long No. 320 OD 3.5 mm (Fig 1). The latter is prepared in the following way: a tube about 15 cm long is threaded onto the stylet and by pulling hard the end of the tube its diameter as well as its wall thickness will decrease. The end will then become tapered to form a short thin walled snugly fitting sheath for the top of the stylet, the tube is cut off squarely through this segment. The distal part of the tube just close to the tip should be bent to an angle of about 90° after steaming. Two side holes should be made in the concavity of this part, most easily done while the stylet lies in the tube.



Fig. 2 Percutaneous nephrostomy. a) Unfavourable position of the 12th rib. The tip of the needle is directed towards the medial wall of the kidney pelvis (\rightarrow). b) Correct position of the 12th rib. The tip of the needle is directed towards the ureteropelvic junction (\rightarrow).

Puncture of the kidney pelvis. The puncture is made with the patient supine under monitoring with a vertical beam. If the function of the kidney is doubtful, an intravenous injection of contrast medium may be helpful for demonstration of the renal pelvis. Since most of the patients suffer from uremia this may well prove useless. Localization of the kidney will then have to be obtained by meticulous screening with an image intensifier of good resolution and high gain.

The external site of puncture chosen is in the axillary line at a level corresponding to the centre of the kidney. The direction of the puncture should be horizontal. Anaesthesia of the skin and underlying tissues is obtained with a thin needle about 9 cm long which should not be allowed to pass into the peritoneum or the intestine. To avoid this complication small amounts of contrast medium should be injected intermittently with the induction of anaesthesia and after the



Fig 3



Fig 4

Fig 3 Exchange of polythene tubes. T-shaped wire guides introduced into the tube their tips lie distal to the ureteropelvic junction

Fig 4 Balloon catheter correctly sited

control of the image intensifier. If necessary the site of puncture has to be chosen at a more dorsal site although this may prove uncomfortable for the patient. The needle is inserted into the kidney to the probable site of the pelvis which, it should be remembered lies at the ventral aspect of the kidney: a sudden flow of urine will indicate that it has been entered. The pelvis is then filled with contrast medium so that its site, size and shape are demonstrated. The needle is then withdrawn and the direction of puncture carefully noted. A small incision is made in the skin for the nephrostomy instrument. The introduction of the combined stylet and tube is checked on the monitor, the direction being that of the needle originally introduced. The sensation transmitted to the fingertips add to the possibility of appreciating the entry of the instrument into the renal pelvis. The stylet is withdrawn and a flow of urine will indicate that the tube is within the pelvis. Contrast medium injected into the tube enables its exact position to be determined and if necessary adjustment of the tube to be made. The tube has to be introduced until the tip reaches the pelvi ureteric junction (Fig 2 b). This manoeuvre is usually quite simple as the tube is curved although occasional

ly the tip will lie up against the medial wall of the pelvis (Fig. 2 a). In such cases a wire guide with its distal tip curved in the shape of the letter J as used in cardiovascular catheterization, is introduced through the tube and gently manipulated into the ureter. The tube is then passed down over the guide wire to the required position and the latter is withdrawn. The tube is fixed to the skin and connected to a urinary bag by a rubber tube.

Technique for permanent nephrostomy. Not infrequently permanent suprapubic diversion is required. The tube is then replaced by a balloon catheter (Foley catheter No. 12) which is more comfortable, may easily be exchanged and is of a diameter that permits adequate diversion. As the diameter of tube No. 320 is rather small the puncture channel must be dilated before passing the larger tubes. The dilatation is performed in the following way: tube No. 320 should lie in situ for 2 to 3 days before being replaced in turn by tube No. 350 (OD 3.99 mm) and after a further 2 to 3 days by tube No. 355 (OD 4.50 mm). The balloon catheter can then usually be inserted two days later. If the tissues are rigid it is sometimes necessary to dilate up to a tube No. 360 (OD 4.82 mm) before the balloon catheter can be introduced. The tubes are exchanged by means of two wire guides (No. 160 diameter 0.90 mm and No. 205 diameter 1.20 mm) usually used for catheterization of arteries. Both guides are introduced into the tube until the tips enter the upper part of the ureter. The tube is withdrawn and the next tube in number is pushed on to the guides until it reaches the required position (Fig. 3). Tubes No. 350, 355 and 360 are prepared in a similar way to that described for No. 320. When the balloon catheter is introduced only the 205 wire guide with a small hole that fits the wire cut out on the top of the catheter is employed (Fig. 4). Anaesthesia is not required on exchanging tubes or catheters. The balloon catheter is replaced once every month; this can easily be done without assistance from the roentgen department.

Results

Nephrostomy of 66 kidneys was performed with good results. Puncture of the pelvis with the instrument described was usually successful at the first attempt but up to three attempts of punctures had occasionally to be made. The tubes or catheters were removed in 16 cases within two months. 3 of these cases were treated early in the series as the position of the tube became unsatisfactory after 2 to 3 weeks and surgical nephropyllostomy had to be performed. The other 35 cases needed permanent nephrostomy and some have had catheters for up to three years.

The flow of urine ceased after a week in one case with a permanent nephrostomy. On control the tip of the catheter proved to lie in the ascending colon: the catheter was removed and no further complications occurred. No other complications occurred in the 55 cases treated. Bleeding from the pelvis through the tube was not infrequently observed during the first few minutes following puncture but ceased spontaneously in spite of the fact that severe haemorrhage is a frequent sequela following operative nephrostomy. Nephroangiography was performed in 18 cases at times varying from 1 hour up to 7 days after the puncture: no evidence of arterial injury was observed. It is of interest that 11 of these cases that were pyrexial before this procedure became afebrile following it.

DISCUSSION

BARTLEY *et coll* (1965), JONSSON *et coll* (1972), MOLIN & ULMSTEN (1971) and SAXTON (1971) have described percutaneous nephropycelostomy to provide for drainage of the renal pelvis for a short time with small attendant risks of complication. Permanent supravescical diversion with this technique is usually not feasible since the catheter is prone either to slip out or be closed by obstruction.

The method presented enables the use of balloon catheters in cases requiring permanent supravescical diversion. This simplifies exchange of catheters and furthermore the catheters retain their positions. The balloon catheters also have a wider diameter than those employed by the above mentioned authors so that blood clots are less apt to cause obstruction. The particular value of the method lies in the positioning of the catheter which allows the patient to rest on his back without interference with the drainage. Percutaneous nephrostomy would thus appear to become the method of choice for both temporary and permanent supravescical diversion. The risk is small and operative nephrostomy should be resorted to only if the new method be unsuccessful.

SUMMARY

A technique of percutaneous nephrostomy for permanent supravescical drainage with balloon catheters is described. The lateral insertion enables the patient to rest on the back comfortably without interfering with the drainage. Operative nephrostomy should be resorted to only in a few selected cases.

ZUSAMMENFASSUNG

Eine Technik für die perkutane Nephrostomie die es ermöglicht oberhalb der Blase eine Drainage mittels eines Ballonkatheters vorzunehmen, wird angegeben. Da der Eingriff an der Seite vorgenommen wird kann der Patient bequem auf dem Rücken liegen ohne den

Katheterabfluss zu storen. Deingemäss sollte eine wirklich operative Nephrostomie nur selten nötig sein.

RÉSUMÉ

Description d'une technique de néphrostomie percutanée à l'aide des sondes à ballonnet pour drainage sur cathéter permanent. L'insertion latérale de la sonde permet au patient un decubitus dorsal confortable qui ne gêne pas le drainage. La néphrostomie opératoire devrait être réservée à quelques cas sélectionnés.

REFERENCES

- BARTLEY O, CHURCHILL N and RILANDER C. Percutaneous drainage of renal pelvis for uremia due to obstructed urinary flow. *Acta chir scand* 120 (1965) 443.
- GOODWIN W E, CAREY W C and WOOTEN W. Percutaneous trocar (needle) nephrostomy in hydronephrosis. *J Amer med Ass* 157 (1955) 801.
- JONSSON M, LINDSTRÖM B and RISTOLIN L. Percutaneous nephropycelostomy in cases of renal obstruction. *Scand J Urol Nephrol* 6 (1972) 51.
- MOLIN J and ULSTRÖM U. Percutaneous nephropycelostomy. *Opusc med* 16 (1971) 70.
- SAXTON H M. Percutaneous nephrostomy. *Brit J Radiol* 44 (1971) 809.
- VELA NAVARRETT R. Repeat direct pyelography via needle nephrostomy. *Acta urol Diagnost* 11 (1971) 33.
- WICKBOM I. Pyelography after direct puncture of the renal pelvis. *Acta radiol* 41 (1951) 300.

EFFICIENCY OF INTENSIFYING SCREENS

SVEN REICHMAN*

The predominant screen phosphor of today is calcium tungstate and has been so for many decades. New systems are however now emerging. BUCHANAN et coll (1972) have stated that screens with rare earth oxysulphide phosphors have certain advantages. Other phosphors consist of barium lead sulphate and certain similar compounds such as barium strontium sulphate. Screens of these substances are now marketed by Kodak Inc. for clinical routine radiography under the label of Kodak X-omatic. Barium lead sulphate is not new. MATTSSON having tested it as early as 1955. Clinical comparison between the X-omatic system and a comparable routine system including calcium tungstate screens and ordinary RP film has now been undertaken to find out whether any difference in image quality could be detected when the two systems were similarly exposed.

Material and Methods The tests were carried out during ordinary routine radiography. Two roentgenograms were obtained for each patient, the centering and field size being used for every pair. The exposure was also identical. When this was not possible owing to sensitivity the tube potential was kept constant. In a few cases



FIG. 1. Tomograms through the ear of skull embedded in plastic. Registration: a) tungsten screens and b) X-omatic screens. The quantum mottle appears as coarse granulation, more evident in (a) than in (b); detail is better in (b).

tomograms obtained at short exposure times—it was deemed of interest to determine whether the X-omatic system might produce films at lower tube potentials than the standard system. These cases will be specially considered.

The pairs of roentgenograms were obtained in the following types of examinations: skeleton of the trunk and extremities; the lungs and colon, as well as in urography, intravenous cholangiography and various types of tomography, including ear tomography of a skull embedded in plastic. The absence of suitable screens prevented the X-omatic system being tested in angiography. Considerable similarities, however, exist between angiography of the abdomen and intravenous cholangiography, so that certain assumptions may be made.

The material consisted of 99 pairs of roentgenograms obtained from adults of all ages; children were not included.

The X-omatic system contains two types of screen: fine for low sensitivity and regular for high sensitivity, and two sorts of film: general for low sensitivity and high for high sensitivity. The sensitivity factor between the two types of screen is 6 to 8, the corresponding value for the films being 2.0. In practice three different combinations are used: the combination of fine screens with high sensitivity film, not being recommended by the manufacturer. The fine screens together with a film of ordinary sensitivity are intended to replace the medical non-screen film. When this latter film was used as a routine it was compared with the screen-film combination just mentioned.



Fig. 2 Tomograms of common bile duct: a) Tungstate screens compared with b) λ -omatic screens: better recording of the low contrast object as in (b). c) A secondary increase in contrast in (a) has not led to improvement.

The reference system consisted of Siemens Saphir screens containing calcium tungstate and Agfa/Gevaert Curix RP film. This system had the same sensitivity as the regular λ -omatic screens combined with the general film. The medical non screen film was the Agfa/Gevaert Osray M intended for roll machine development. This might suggest that the investigation was primarily a comparison between Kodak screens and films on the one hand, and Siemens screens and Agfa/Gevaert films on the other. Every reason may however be given that the choice of manufacturer has but a marginal influence. Standard screens and films made by Kodak should consequently not be expected to differ significantly from the reference system employed.

Results

These should be prefaced by a consideration of what happens to a screen-film combination when exposed to roentgen rays without any object being inserted into the roentgen beam. Theoretically completely homogeneous density of the film should be obtained after development: this however does not occur but is replaced by two types of inhomogeneity. The first is due to the graininess



Fig. 1. Tomograms through the ear of a skull embedded in plastic. Registration with a) tungstate screens and b) X-omatic screens. The quantum mottle appears as coarse granularity more evident in (a) than in (b); detail is better in (b).

tomograms obtained at short exposure times—it was deemed of interest to determine whether the X-omatic system might produce films at lower tube potentials than the standard system. These cases will be specially considered.

The pairs of roentgenograms were obtained in the following types of examinations: skeleton of the trunk and extremities; the lungs and colon; as well as in urography, intravenous cholangiography, and various types of tomography, including ear tomography of a skull embedded in plastic. The absence of suitable screens prevented the X-omatic system being tested in angiography. Considerable similarities, however, exist between angiography of the abdomen and intravenous cholangiography, so that certain assumptions may be made.

The material consisted of 99 pairs of roentgenograms obtained from adults of all ages; children were not included.

The X-omatic system contains two types of screen: fine for low sensitivity and regular for high sensitivity; and two sorts of film: general for low sensitivity and high for high sensitivity. The sensitivity factor between the two types of screen is 6 to 11, the corresponding value for the films being 2.0. In practice three different combinations are used: the combination of fine screens with high sensitivity film not being recommended by the manufacturer. The fine screens together with a film of ordinary sensitivity are intended to replace the medical non-screen film. When this latter film was used as a routine it was compared with the screen film combination just mentioned.



Fig 4 Part of the sigmoid colon filled with barium sulphate \ significant difference in image quality between a) tungstate screens and b) \ L-cromatic screens

constantly observed on comparison of these two screen film combinations that the quantum mottle was more easily visible in the calcium tungstate alternative which also had a lower detail resolution.

The visibility of the quantum mottle was about the same in the high sensitivity L-cromatic combination as in the calcium tungstate reference system. Since the sensitivity could thus be increased by 100 per cent without any increase in quantum mottle visibility it appeared especially worthwhile to test it in intravenous cholangiography. In this type of examination the author always takes linear tomograms to keep the exposure time low so as to avoid movement unsharpness (REICHMANN 1973). The tube potential must however also be kept down and a compromise is usually necessary for this reason the voltage often becomes higher than desirable. This conflict between exposure time and low potential is the same as is so often encountered in angiography of the abdomen. The reference system was consequently compared with the high sensitivity L-cromatic system. The potential in the case in Fig 2 was thus reduced from 75 to 69 kV and obviously produced a better recording. The disturbing mottle was the same in the two alternatives but since the image itself had a higher contrast with the L-cromatic system an increase in low contrast detail was obtained. When the quality of a screen film system is discussed its rendering of contrast is often stressed. It is important. However if the contrast be increased by means of a harder developing film, then the visibility of the quantum mottle together with this improvement in image will increase. The tomogram in Fig 2 was copied with higher contrast (Fig 2 c) to demonstrate that the quantum mottle rather than the contrast rendering of this system is the limiting factor



Fig 5 Bone structure in roentgenograms obtained at 130 kV. Mottle masks fine detail with a) tungstate screens but b) not with X-omatic screens

With a term borrowed from the technology of sound amplification quantum mottle is denoted as a kind of disturbing noise while the image is called the signal. It is evident that the signals should as much as possible be stronger than the noise. When Figs 2 a and c are compared, it is apparent that the signal/noise ratio has not been altered: the visibility of both has increased equally. To pursue the analogy with a sound amplifier, the contrast function of the screen-film system may be compared with the loudness control. An increase in film contrast resembles an increase in sound volume. Both signals and noise will be more easily discernible but it will not become easier to separate them. The X-omatic system as used in the example (Fig 2) resulted in a constant noise but an improved signal. The signals thus became easier to differentiate from the noise: more detail without disturbance by the quantum mottle was apparent.

The signal/noise ratio may be made increasingly favourable by means of increased signal intensity, as was described in the foregoing. This increase is obtained by means of a lowering of the tube potential. Signal intensity may however be kept constant and the noise lowered. This is the alternative already illustrated in Fig 1. This technique proved to be preferable in two cases: (a) when very fine detail was to be recorded (cf Fig 1) and (b) when it was undesirable to lower the voltage. The latter is encountered in radiography of the lung and led to the reference system being compared with the medium sensitivity X-omatic system in such examinations. A surprising increase in detailed rendering of the pulmonary structures was obtained (Fig 3).



Fig 6 Distal end of fractured radius. Recording made with (a) medical non screen film and (b) the lowest sensitivity automatic alternative with which detail of the skeleton is somewhat better recorded.

The object in some types of examination regularly gives rise to relatively favourable signal/noise ratios owing to high absorption capacity. This obtains in gastro intestinal examinations with barium sulphate as contrast medium. It also occurs in skeletal radiography of subjects not displaying osteoporosis if a suitably low tube potential be used. In these categories the reference system was compared only with the medium sensitivity automatic system simply because the automatic exposure procedure allowed no other type of comparison. The two types of roentgenogram differed in background mottle but since the signals were well above the noise level the difference in image quality was not considered to be diagnostically important (Fig 4).

The examinations of the colon were performed at 130 kV. The image pairs revealed a clear difference in the recording of the skeleton so that the low noise system in fact afforded an acceptable depiction of the bone structure in spite of the high tube potential. The background mottle in the reference images was so intense as to mask these structures (Fig 5). The recording of the skeleton was thus not altered by a low tube potential but it became dependent on the noise level when the potential was increased and the signal intensity correspondingly decreased.

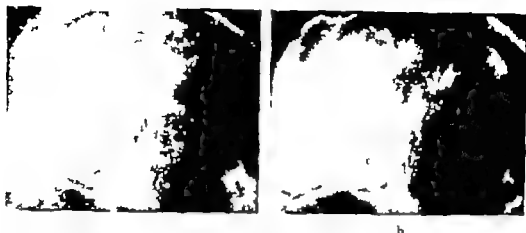


Fig Bone structure in roentgenograms obtained at 130 kV Mottle masks fine detail with a) tungstate screens but b) not with X-omatic screens

With a term borrowed from the technology of sound amplification quantum mottle is denoted as a kind of disturbing noise while the image is called the signal. It is evident that the signals should as much as possible be stronger than the noise. When Figs 2 a and c are compared it is apparent that the signal/noise ratio has not been altered: the visibility of both has increased equally. To pursue the analogy with a sound amplifier the contrast function of the screen-film system may be compared with the loudness control. An increase in film contrast resembles an increase in sound volume. Both signals and noise will be more easily discernible but it will not become easier to separate them. The X-omatic system as used in the example (Fig 2) resulted in a constant noise but an improved signal. The signals thus became easier to differentiate from the noise: more detail without disturbance by the quantum mottle was apparent.

The signal/noise ratio may be made increasingly favourable by means of increased signal intensity as was described in the foregoing. This increase is obtained by means of a lowering of the tube potential. Signal intensity may however be kept constant and the noise lowered. This is the alternative already illustrated in Fig 1. This technique proved to be preferable in two cases: (a) when very fine detail was to be recorded (cf Fig 1) and (b) when it was undesirable to lower the voltage. The latter is encountered in radiography of the lung and led to the reference system being compared with the medium sensitivity X-omatic system in such examinations. A surprising increase in detailed rendering of the pulmonary structures was obtained (Fig 3).

Discussion

The λ -omatic system proved to have less visible quantum mottle in a sensitivity identical with that of the reference system. Paradoxically, it may happen that screen-film combinations of a relatively low quality may give rise to less visibility of the quantum mottle than a high quality combination. This is due to a spreading out of the light within the poorer screens so that quantum mottle is also depicted with such unsharpness as to become indistinct in spite of its presence (ROSSMAN 1964). At the same time the screens with a low quantum mottle invariably render poorer detail and faint signals. Since the λ -omatic system gave an improved recording of these kinds of signals and less visible quantum mottle, there appeared to be justification for assuming that true lowering of the quantum mottle did occur.

This investigation seems to have demonstrated that quantum mottle is an important factor in limiting the information capacity of clinical roentgenograms. It would also appear that not all types of examination suffer equally from the influence of noise. In principle the reference and λ -omatic systems produced similar recordings of signals which were well above the noise level provided the detail was not too fine. Since the noise level of the reference system may in these cases be accepted, a dose reduction may be obtained with the high sensitivity λ -omatic alternative: both patients and tubes will benefit. An attempt has been made in the Table to suggest which types of λ -omatic films and screens may be preferable in different examinations.

A comparison between the reference system and the λ -omatic alternative of identical sensitivity suggests that the image of the latter is built up of more photons even though the dose, i.e. the total number of photons striking the front screen, is unaltered. This should be regarded as a true improvement in efficiency. However, the term efficiency is used in a somewhat confusing way when applied to intensifying screens. The common means of expressing the efficiency of an intensifying screen is by the roentgen-to-light conversion factor. The roentgen energy absorbed is measured and compared with the output of light energy. A high conversion factor is considered favourable: it is present when large amounts of light are obtained from small amounts of roentgen photons. Another not so clearly defined way of expressing the same thing is by means of the intensification factor: the roentgen dose necessary for blackening the film without screens is compared with the dose required when screens are used. Since the characteristic curve of the film is grossly changed by screens, the intensification factor should be abandoned altogether. The conversion factor remains unaltered, however, from a physical point of view, still its validity for the measurement of screen quality must be questioned.

BUCHANAN *et coll* recently presented two new screen phosphors with considerably higher conversion factors than calcium tungstate to a lesser degree these phosphors also have a higher capacity to absorb roentgen photons. The gain in conversion factor was stressed by the authors, but perhaps not rightly so however since it is the absorptive capacity and not the conversion factor that determines the number of photons that will participate in forming the final image. Even if its conversion factor be low a new type of screen will represent true progress if only the absorptive capacity be high the low conversion factor can be balanced by a film of higher sensitivity.

SUMMARY

Quality in routine radiography is often limited by quantum mottle. This can be reduced without an increase in dose if the film or screen film system takes up a larger fraction of the radiation that passes through the object. The absorptive capacity is thus a good measure of the efficiency of a recording medium and this has been demonstrated by a comparison of two screen film systems.

ZUSAMMENFASSUNG

Die Qualität von Routine-Röntgenbildern ist häufig durch die Quantenflecksigkeit begrenzt. Diese kann ohne einen Anstieg der Dosis vermindert werden wenn der Film oder das Schirmbildsystem einen grösseren Teil der Strahlung die das Objekt passiert aufnimmt. Die absorptive Kapazität ist daher ein gutes Mass der Effektivität eines registrierenden Mediums. Dies wurde bei einem Vergleich von zwei Schirmbildsystemen gezeigt.

RÉSUMÉ

La qualité des films dans le travail radiologique habituel est souvent limitée par le grain quantique. Cela-ci peut être réduit sans augmentation de la dose si le film ou le système écran film enregistre une plus grande fraction du rayonnement qui passe à travers l'objet. La capacité d'absorption est ainsi une bonne façon de mesurer l'efficacité d'un moyen d'enregistrement et ceci a été démontré par la comparaison de deux systèmes écran film.

REFERENCES

- BUCHANAN H. A., FINKELSTEIN S. I. and WICKERHAUSEN K. A. X-ray exposure reduction using rare-earth oxysulphide intensifying screens. *Radiology* 105 (1973) 185.
 BUCHSTRÖM H. och LUNDH A. Det röntgenfotografiska materialet och dess behandling. I BUCHSTRÖM H. *Fotografisk handbok* (In Swedish) Natur och Kultur Stockholm 1970.
 MATTISON O. Practical photographic problems in radiography. *Acta radiol* (1973) Suppl. No. 170.
 REICHMANN S. Tomography of moving objects. *Acta radiol. Diagnosis* 14 (1973) 312.
 ROHMANN K. Some physical factors affecting image quality in medical radiography. *J. Phot. Sci.* 12 (1964) 29.

A MATHEMATICAL MODEL OF NARROW BEAM ROTATION METHODS

ULF WELANDER

The first suggestions that a rotating narrow beam might be used to obtain special radiologic projections were put forward by VALLBOOM (1930) and HELLMAN (1939). A method for exposing panoramic images of the jaws, using a rotating beam, was developed from the works presented by PAATERO (1949, 1954) and is today in wide use in odontologic roentgen examinations.

PAATERO's method (pantomography) was presented as a modified form of tomography adapted for application to a curved layer and the mathematical analyses of the method presented up to now have been based on this premise (HUDSON *et al.* 1957, DURAMEL 1954, 1957, SOTLA 1961, TAMMISALO 1964, TAMMISALO & NIEMINEN 1964). DURAMEL (1957) maintained that the image is composed of a series of tomograms whose widths correspond to the width of the beam.

The principle underlying the methods based on a rotating narrow beam differs fundamentally from that of true tomography; however, WELANDER & NYSTROM (1971) have demonstrated empirically that the rotating slit method creates an imaginary focus at the rotation centre of the beam; this rotation focus constitutes the source of the rays in a central projection. The blurring and

Submitted for publication 15 June 1973

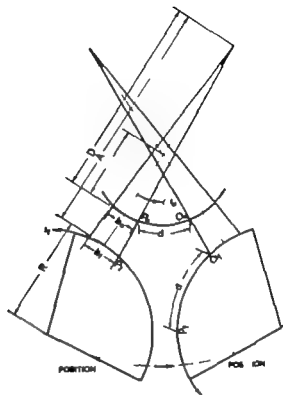


Fig 1 The principle for exposure of curved object by means of rotating narrow beams and a moving film. The figure illustrates two positions between which continuous movement takes place during the depicting of the distance d in the object.

magnification of the image in this projection is controlled by giving the film a suitable velocity in relation to the object and the beam during the exposure. The image on the film may be defined as an orthoradiographic representation of a curved object.

Using the theory concerning the principle of rotating slit method described by WELANDER & NYSTROM a mathematical model of such method which is valid for the rotation plane, the horizontal plane, is presented in this paper. The conditions in the vertical plane have been excluded.

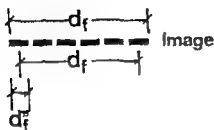
Mathematical model

Definitions (See Figs 1 and 2)

d = distance in the object

d_f = length of the distance d projected on the film

d_f = true length of the distance d projected on the film when the characteristic blurring is eliminated



$$U_w = |d_f'| \quad d_f = d_f + U_w$$

Fig 2 Schematic representation of the relation between the length of distance in the object (d_o) projected on the film (d_f) and the true length of the distance in the film (d_f'). d_f' is the length of point in the object projected on the film.

M = magnification factor $\frac{d_f}{d_o}$

d_f = length of a point in the object projected on the film direction of projection movement is shown by positive or negative sign

U_w = characteristic unsharpness of rotating narrow beam methods d_f

r = radius of the object

R = radius of the film

= angular velocity of the beam

ω_f = angular velocity of the film

b = width of the beam in the object

b_f = width of the beam on the film

D = distance tube target to object

A = distance target to film

t = exposure time

The symbols and definitions agree wherever applicable with the norms recommended by the ICRU (1962)

Deduction

Fig 1 shows the principle for exposure of an image of a curved object by means of a rotating narrow beam and a moving film the target is assumed to be of negligible size

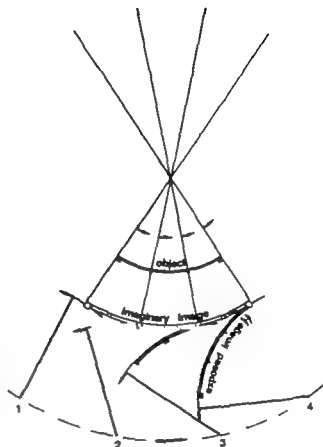


Fig. 3 The rotation center as source of the rays (rotation focus) produces an imaginary image whose size in relation to the object is directly proportional to the rotation focus—film and rotation focus—object distance. The imaginary image is exposed successively on the moving film and its length dimension can be altered.

From the moment when one of the marginal rays of the beam enters the distance d in the object at the point P (position 1) until the other marginal ray leaves the distance d at the point Q (position 2), the central ray travels the distance

$$d + b$$

During the exposure time t the central ray travels in relation to the object the distance

$$rc = t$$

Thus

$$d_0 + b = rc \cdot t$$

$$t = \frac{d_0 + b_0}{rc \cdot c_0} \quad (1)$$

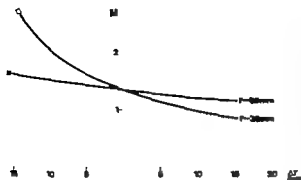


Fig. 4 The magnification factor M as a function of an increment d to the radius of the object. The indicated functions are also for the anterior rotation centre and the first part of the lateral rotation centre in the Orthopantomograph 3. $R = 165 \text{ mm}$, $r = 28 \text{ mm}$, $r_0 = 89 \text{ mm}$. $\frac{dM}{dd} = 0.228$ and $\frac{dM}{dd} = 0.729$ respectively.

In position 1 the object point P is depicted on the film in the point P_f and in position 2 the object point Q is depicted in the point Q_f . The distance d is depicted successively on the film as the distance d_f . The total distance travelled by the central ray in relation to the film from the moment when one of the marginal rays is in the point P_f until the other marginal ray is in the point Q_f is

$$d_f + b_f$$

During the exposure time t , the film travels, in relation to the central ray, the distance

$$R\omega t$$

Thus

$$d_f + b_f = R\omega t$$

$$t = \frac{d_f + b_f}{R\omega} \quad (2)$$

The exposure time t is common to equations (1) and (2). It is thus true that

$$\frac{d_f + b_f}{R\omega} = \frac{d_0 + b_0}{r\omega_0}$$

Removing d_f we get

$$d_f = \frac{R\omega}{r\omega_0} (d_0 + b_0) - b_f \quad (3)$$

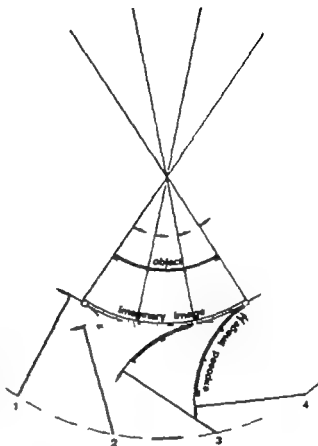


Fig. 3 The rotation centre of the rotation focus produces an imaginary image whose size relative to the object is directly proportional to the rotation focus—object distance. The imaginary image is exposed successively on the moving film and its length dimension can be altered.

From the moment when one of the marginal rays of the beam enters the distance d in the object at the point P (position 1) until the other marginal ray leaves the distance d at the point Q (position 2) the central ray travels the distance

$$d + b_0$$

During the exposure time t the central ray travels in relation to the object the distance

$$r \omega t$$

Thus,

$$d + b_0 = r \omega t$$

$$t = \frac{d_0 + b_0}{r \omega_0} \quad (1)$$

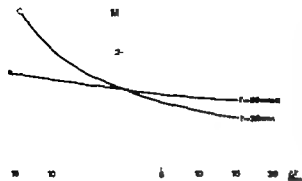


Fig. 4 The magnification factor M as function of an increment Δ to the radius of the object. The indicated functions are also for the anterior rotation centre and the first part of the lateral rotation centre in the Orthopantomograph 3. $R = 165$ mm, $r_1 = 78$ mm, $r_2 = 69$ mm, $\frac{dr_1}{d\Delta} = 0.228$ and $\frac{dr_2}{d\Delta} = 0.729$ respectively.

In position 1 the object point P is depicted on the film in the point P_1 and in position 2 the object point Q_0 is depicted in the point Q_1 . The distance d_0 is depicted successively on the film as the distance d_1 . The total distance travelled by the central ray in relation to the film from the moment when one of the marginal rays is in the point P_1 until the other marginal ray is in the point Q_1 is

$$d_1 + b_1$$

During the exposure time t , the film travels in relation to the central ray the distance

$$R\omega t$$

Thus

$$d_1 + b_1 = R\omega t$$

$$t = \frac{d_1 + b_1}{R\omega} \quad (2)$$

The exposure time t is common to equations (1) and (2). It is thus true that

$$\frac{d_1 + b_1}{R\omega} = \frac{d_0 + b_0}{r\omega_0}$$

Removing d_1 we get

$$d_1 = \frac{R\omega}{r\omega_0} (d_0 + b_0) - b_1 \quad (3)$$

The relation between the width of the beam in the object and on the film is directly proportional to the relation between the distances target—object and target—film

$$\frac{b_o}{b_f} = \frac{D}{\lambda} \quad b_o = \frac{b_f D}{\lambda}$$

With the film and object radii and beam widths used in practical systems for exposing images by narrow beam rotation the curvature of the object and of the film in the beam is negligible (TAMMISALO & NIEMINEN 1964). Using this approximation b in equation (3) may be expressed as a function of b_f in the following. b_f is used to symbolize the width of the beam on the film to denote that the approximation has been performed. We then get the following expression

$$d_f = \frac{R\omega}{r\lambda\omega} \left(d_o + \frac{b_f D}{\lambda} \right) - b \quad (4)$$

Application

The geometrical proportions of the image In theory an image without blurring can be produced with the narrow beam rotation method if the beam is of negligible width. The true length in the image of an object will thus be obtained from (4) if $b_f \rightarrow 0$

$$d = \frac{R\omega d_o}{r\lambda\omega}$$

From this expression it appears that the true length of the image is directly proportional to the ratio of the velocity of the film to that of the beam but is independent of the target—object and target—film distances. This means that the projection is determined by the factors that are parameters in a central projection which has the rotation centre as source of the rays, the rotation focus (Fig. 3).

At different distances Δr from the radius of the object r the length of the image will be

$$d = \frac{R\omega d_o}{(r + \Delta r)\omega} \quad (5)$$

The magnification expressed as the ratio of the true length of the image to the length of the object is

$$M = \frac{d_f}{d_o} = \frac{R\omega}{(r + \Delta r)\omega} \quad (6)$$

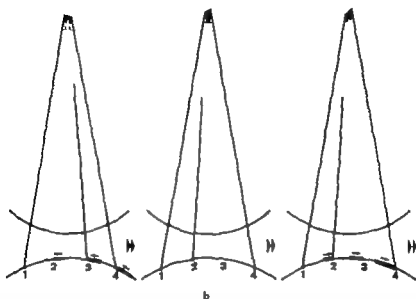


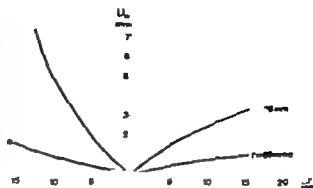
Fig. 5. A point exposed in four positions while passing narrow beam. Both the object and the film move from left to right in the figure. A point in the object will be sharply depicted when the projection of the point on the film is stationary in relation to the film (b) this applies in divergent beam when the film has somewhat higher velocity than the object. When the film moves at higher velocity than the projection of the point on the film the direction of the point's projection is negative (arrows). When the film moves at lower velocity than the projection of the point on the film the direction of the point's projection is positive (arrows).

$M = f(\Delta r)$ is exemplified in Fig. 4 with the values valid for the anterior rotation centre and the lateral rotation centre in the Orthopantomograph 3. For the continuous transition between the two rotation centres M is variable continually in the interval between the functions.

The characteristic blurring of the image. Unsharpness has been defined as the point spread function which includes the energy distribution in the image plane (ROSSMANN 1969). It seems sufficient for the present purpose however simply to regard the blurring occurring with the rotating narrow beam methods as the length of the point spread function i.e. the length of a point's projection on the film. This will be obtained from (4) when $d \rightarrow 0$.

$$d = \frac{R \sin b_r D}{r \sin \Lambda} \rightarrow b_r \quad (7)$$

FIG. 6 The unsharpness U_w as a function of an increment Δr to the radius of the object r . The functions indicated are valid for the anterior rotation centre and the first part of the lateral rotation centre in the Orthopantomograph 3 with a beam width of 10 mm. $R = 163$ mm, $D_1 = 340$ mm, $D_2 = 343$ mm, $A = 460$ mm, $\omega = 78$ mm, $\phi = 89$ mm.



According to this expression, the length of a point's projection is directly proportional to the width of the beam and is dependent on the distances target—film and target—object. These factors are parameters in a central projection with the tube target as the focus and they thus determine the unsharpness of the image. However the total length of a point's projection on the film is also affected by the relation between the film velocity and the beam velocity in the object (Fig. 5).

The length of a point's projection is obtained from equation (7). Outside a sharply depicted plane the projection of a point in the object will move in relation to the film while the beam passes the object. The direction of this movement is different on each side of the sharply depicted plane. The direction of the point's projection is indicated by a positive or a negative value for d_1 when the equation is solved. The blurring however is not dependent on the direction of the point's projection, $U_w = |d_1|$. Thus at different distances Δr from the radius of the object, r

$$U_w = \left| \frac{R_{obj} (D + \Delta r) - b_1}{(r + \Delta r) \omega A} \right| \quad (8)$$

With the values valid for the anterior and lateral rotation centres in the Orthopantomograph 3 the functions for $b_1 = 10$ mm (Fig. 6) are obtained from this expression. For the continuous transition between the rotation centres U_w varies continually in the interval between the functions.

The resultant image. Equation (4) is of universal application and gives the characteristics of the exposed image when the different factors are varied independently of one another. If satisfactory sharpness of the image is to be obtained by narrow beam rotation the characteristic blurring must be eliminated

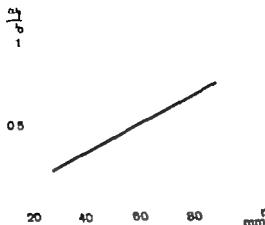


Fig 7 $\frac{\omega_f}{\omega_o}$ as function of the radius of the object. $R = 165$ mm $H = 340$ mm $A = 460$ mm and $28 \leq r \leq 89$ mm. The line constitutes an approximation of the transition from the anterior rotation centre to the beginning of the lateral rotation centre in the Orthopantomograph 3.

in part of the object. Equation (7) provides the relation between the velocities of the film and of the beam that must apply in order to make $U = 0$. We get this from

$$\frac{R\omega_f b_f D}{r r_0 A} = b_r$$

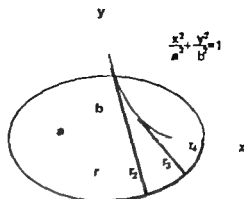
$$\frac{\omega_f}{\omega_o} = \frac{r A}{R D} \quad (9)$$

$\frac{\omega_f}{\omega_o} = f(r)$ is illustrated in Fig 7

From equation (9) it is apparent that the relation between the film velocity $R\omega_f$ and the beam velocity in the object $r\omega_o$ must be proportional to the relation between the target film and target object distances if the unsharpness is to be eliminated in part of the object. In consequence the geometrical proportions will be affected and the image will be magnified (cf equations (6) and (8) and the functions in Figs 4-6).

Thus an image produced by means of a rotating narrow beam is composed of two central projections one of which has the rotation centre (rotation focus) and the other the tube target as the focus. The simultaneous effect of the two projections on the nature of the image may be analysed with the aid of equation (4) which may be used as a mathematical model of rotating narrow beam methods.

Fig. 8. Elliptical movement. The rotation focus moves along the elliptic orbit of the ellipse. The effective projection radius for each part of the movement along the ellipse is the length of the perpendicular to the point where it is tangent to the ellipse.



In summary, the mathematical model may be written

$$d_I = d + U_w = \frac{R_{eff} d_0}{r_{eff}} + \left| \frac{R_{eff} b_r D}{r_{eff} \lambda} - 1 \right|$$

The equation is valid for a circular movement but can be applied in other movements if r is substituted by an adequate function. For an elliptical movement the following is valid

$$r(x) = \frac{(a + x(b - a))}{a}$$

where r is increasing or decreasing in the interval where $-a \leq x \leq a$ (Fig. 8)

Discussion

The systems in which a rotating narrow beam is used (VALLBOGA 1930; HUELMANN 1939; PAATERO 1949, 1954; VLOKOV 1957) have been classified as tomographic methods (ICRU 1962) but these systems do not coincide with the definitions of tomography (LIDHOLM 1960); they should instead be described as methods for producing orthoradiographic images of curved objects (WFLANDER & NYSTROM 1971).

As a result of unclear definitions the mathematical expressions derived for these rotation methods on the presupposition that a defined tomographic layer is present in the object plane have been incompletely and to a certain extent incorrectly interpreted. In the calculation of the geometrical proportions of the image the distance in the image between two points in the object has thus been summated—or subtracted—with the projection lengths of the points (TAMM

SALO 1964) with the result that a calculated distance has been affected by the magnitude of the unsharpness. The length of a point's projection on the film has been calculated by TAMMISALO & NIEVINEN (1964). Their result is the same as the function obtained from equation (7) but this does not indicate that there is a defined tomographic layer in the object plane. The derivation of the mathematical expressions of TAMMISALO and TAMMISALO & NIEVINEN was based on the supposition that the unsharpness is eliminated in the object plane when the relation between the film and beam velocities is directly proportional to the distances target—film and target—object. This presupposition is correct but it leads to an incomplete mathematical expression. Their formula for the calculation of the length of a point's projection on the film is cancelled when a variable factor Δr is absent and the other factors therefore cannot be varied unconditionally.

The functional principle of the rotating slit methods can only be fully understood if the characteristics of the image with respect to length dimension and blurring and the image forming factors are given clear cut definitions. In the derivation and application of the mathematical model presented in this report the rotating slit systems were strictly defined.

The mathematical model demonstrates that an image produced with a rotating narrow beam is composed of two central projections acting simultaneously. The beam from the imaginary source rotation centre (rotation focus) determines the geometrical proportions of the image and is the essential image forming beam while the beam from the tube target produces the blurring. The two projections are influenced in several ways by the same factors, but are independent of each other as is evident from the fact that the mathematical model constitutes the sum of two separate expressions one for each projection.

When a point is projected in different directions on both sides of a sharply depicted part of the object the blurring occurring with rotating narrow beam methods will have a superficial resemblance to tomographic blurring but does not tally with the definitions of the latter type (EDHOLM 1960). The unsharpness furthermore, does not have the same effect or function as in tomography. In the rotating narrow beam methods it is a pseudotomographic side effect arising from the fact that a central projection of the curved object cannot for practical technical reasons be achieved with negligible width of the beam. The blurring that occurs with narrow beam rotation methods should be regarded as a geometrically determined motion blur which is typical of these methods. In the special case in which there is no relative motion between object and film $R_1 = r_0$ and in which the curvature of film and object is negligible the characteristic blurring is identical with the unsharpness seen in the orthoradiographic methods of HECHMANN (1939) and MALVONEN (1951).

SUMMARY

A mathematical model of the rotating narrow beam methods has been derived and applied in order to describe the principle for the functioning of the methods. It may be applied in general in the search for the optimal conditions for narrow beam rotation in comparisons between different systems based on such rotation and in calculations of the geometrical proportions and blurring in the exposed image.

ZUSAMMENFASSUNG

Es ist ein mathematisches Modell für die Methoden mit einem rotierenden schmalen Strahlenbündel hergeleitet und angewandt worden um das Prinzip der Funktion dieser Methode zu beschreiben. Es kann generell verwendet werden um die optimalen Bedingungen für die schmal Strahlenbündelrotation festzustellen, verschiedene Systeme die auf einer derartigen Rotation aufbauen miteinander zu vergleichen und um die geometrischen Proportionen und Unschärfe des exponierten Bildes zu berechnen.

RÉSUMÉ

L'auteur a établi un modèle mathématique des méthodes utilisant un faisceau étroit tournant et a appliqué ce modèle à la description du principe de fonctionnement de ces méthodes. Ce modèle peut être appliqué en général pour rechercher les conditions optimales de rotation du faisceau étroit pour comparer différents systèmes basés sur cette rotation et pour calculer les proportions géométriques et l'effet de l'image exposée.

REFERENCES

- DILLON J. Les procédés de radiographie en coupe non rigoureux. *Science et industries photographiques* 25 (1954) 129.
 — Sur la correspondance entre les espaces image et objet dans les procédés de radiographie en coupe par faisceau diaphragmé. *Science et industries photographiques* 28 (1957) 225.
 EDWARDS P. The tomogram. Its formation and content. *Acta radiol.* (1960) Suppl. No. 193.
 HECKMANN H. Die Röntgenperspektive und ihre Umwandlung durch eine neue Aufnahmetechnik. *Fortschr. Röntgenstr.* 60 (1939) 144.
 HODSON D. C., HUMPHREY J. W. and DILLON J. A panoramic X-ray dental machine. *U.S. Armed Forces Med. J.* 8 (1957) 46.
 ICRU. Methods of evaluating radiological equipment and materials. Report 10 of 1962. National Bureau of Standards Handbook 89. Washington, D.C. 1963.
 MALA OSMUND J. Présentation de radiographies obtenues grâce à un nouvel appareil permettant à la fois l'orthoradiographie et la planigraphie. *J. Radiol. Électrol.* 32 (1951) 66.
 NYSTRÖM O. and WELANDER U. Image producing geometry and tomography in roentgenologic narrow beam methods. *Swed. Dent. J.* 64 (1971) 64.
 — — A new theory on the image producing elements in pantomographic methods. *DNF Rad. I* (1972) 3.
 PAATERO Y. V. A new tomographical method for radiographing curved outer surfaces. *Acta radiol.* 32 (1949) 177.
 — Pantomography in theory and use. *Acta radiol.* 41 (1954) 321.

- ROSEMARY K. Point spread function, line spread function and modulation transfer function. Tools for the study of imaging systems. *Radiology* 93 (1969) 457.
- SOLA P. General theory of narrow beam rotating tomography. *Acta radiol* 33 (1961) 458.
- TAKKIALA E. II. The dimensional reproduction of the image layer in orthopantomography. *Suom. Hammaslaak. Toinn* 60 (1964) 2.
- and NURMINEN T. The thickness of the image layer in orthopantomography. *Suom. Hammaslaak. Toinn* 60 (1964) 119.
- VALLEBONA A. Una modalita di tecnica per la dissociazione radiografica delle ombre applicata allo studio del cranio. *Radiol. méd.* 17 (1930) 1090.
- VONDER P. Segmental roentgenography by means of a standard tomographic device. *Acta radiol* 48 (1957) 181.
- WELANDER U and NYSTRÖM O. A new approach to the theory of pantomographic methods. *Swed. Dent. J.* 64 (1971) 173.

RADIOLOGIC EXAMINATION OF THE SMALL INTESTINE BY DUODENAL INTUBATION

J L SELLINK

Although the roentgen examination of the small intestine has been a common procedure for the past 70 years the results unfortunately still give little cause for satisfaction. While knowledge of the diseases of the small bowel has increased considerably the radiologic examination has hardly changed. As a result of diverging views a number of techniques have been developed, these differ to such an extent that the average transit time may vary from 1 to 6 hours. This is perhaps not surprising in view of the fact that the time is dependent upon factors such as the amount, caloric and osmotic values as well as the temperature and method of administration of the contrast medium. In addition the number of media on the market continues to grow although even today none approaches the ideal. Standardization of the method of examination and the contrast medium has been suggested.

BRAECKMAN (1947) analysed the influence of particle size and the addition of hydrophilic colloids on the rate of sedimentation of a barium sulphate suspension and plotted the results against time (Fig. 1). ZIMMER (1948) was one of the first to investigate flocculation *in vitro* by adding substances from the digestive tract, such as mucin, fatty acids and gastric juice, that enhance the phenomenon. The percentage of flocculation was also recorded against time (Fig. 2). The curves of BRAECKMAN and ZIMMER proved to be practically identical and in

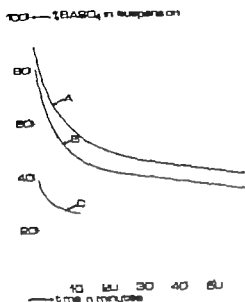


Fig 1 Difference in rate of sedimentation (after *Beauchamp*) (A) BaSO_4 + 0.01% gum arabic B) BaSO_4 + 7.5% gum arabic C) BaSO_4 + 0.01% Na citrate

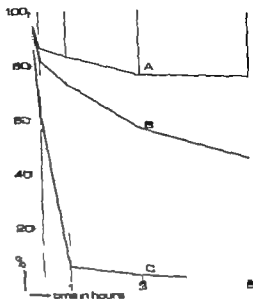


Fig 2 Sedimentation curves of *Zoonen* (1949) Difference between A) Alubar Wandaer B) high quality brand and C) barium suspension with thio adducts

indicated that these media quickly settle out of suspension. Sedimentation is of course of little importance in the lumen of the continuously contracting small bowel; there it is only a matter of chemical flocculation. Flocculation of a barium suspension and its disintegration into increasingly large clumps is a physicochemical process that increases with the transit time. Clumping is further enhanced by the physiologic withdrawal of water from the suspension in the distal part of the ileum and in the colon. Unfavourable conditions, as for instance in diseases of malabsorption and inflammation, will cause the most rapid changes in the contrast medium. Once flocculation or segmentation has developed, anatomically true representation of the intestinal lumen is an illusion (Fig 5). It is therefore most necessary to increase the rate of transit so that the caecum is reached as quickly as possible; the roentgenogram should be obtained only while the barium is still in suspension.

This view was confirmed by clinical experience: serious cases sometimes allow only 10 or 15 minutes for mucosal patterns (Fig 4). In addition, it is hardly surprising that drugs that accelerate transit, such as Sorbitol (*POWCHER & CAROL*, 1957) and Metoclopramide (*JAMES & HUME*, 1968) produced a definite im-



Fig. 3. Jejunal loop in case of liposarcoma. a) Homogeneous contrast column. The narrow spaces between the coarse mucosal folds are filled with medium and clearly visible. b) Disintegration of the barium suspension a few moments later. Splotty appearance of contrast column. No mucosal folds visible.

improvement in the mucosal patterns, especially in the ileum where the detrimental effect of removal of water from the suspension then also decreased.

The acceleration in the passage obtained by WEINTRAUB & WILLIAMS (1949) who administered 2×200 ml ice-cold normal saline subsequent to the examination of the stomach had of course an adverse effect on the quality of the mucosal patterns. It is also understandable that larger amounts of medium administered in the shortest possible time, as long advocated by MARSHAK & LINDNER (1970) offer the best buffer action against the damaging effect of gastric and intestinal



Fig. 4 a) Conventional gastrointestinal transit examination in malabsorption syndrome of unknown nature b) Same examination a week later with the author technique Improved filling of (distended) intestinal loops without signs of disintegration of the contrast medium

200 ml doses

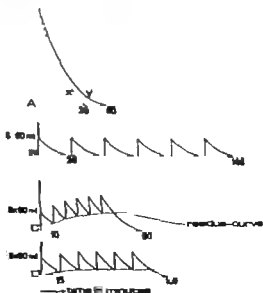


Fig. 5 A) Gastric emptying curve (—) sitting or standing position (---) right lateral position B) Ideal fractionation Rate of supply equals rate of emptying C) D) Fractionation Rate of supply is greater than rate of emptying increasing residue in the stomach.



b



d

Fig. 6) b) Normal mucosal pattern.) d) Disintegration of the contrast medium in the same intrastinal loop. Flattening and apparent coarsening of the mucosal folds. The structure of the medium has become granular (clearly visible in the original film).



Fig 7



Fig 8

Fig 7 Small intestine flooded with water practically all the medium lies in the colon

Fig 8 Double contrast examination of the colon immediately after that of the small bowel. Air injected through duodenal tube

juices. Possible flocculation is thus moved to a later period in the examination as well as to a more distal location. The frequent administration of small amounts of medium as described by PANDORF (1937) and now used by LASSIICH among others has on the other hand an unfavourable effect on the suspension and therefore on the quality of the film. The stomach then empties much more slowly (Fig 5) so that the medium remains in contact with larger quantities of gastric and intestinal juices for longer periods.

It thus appeared that the administration of larger quantities (500 to 600 ml) of a stable barium suspension, the stimulation of gastric emptying by drugs that enhance peristalsis and positioning of the patient on the right side must provide a sufficient guarantee for good mucosal patterns under all circumstances in the event of serious malabsorption and inflammatory diseases. Numerous illustrations even in up-to-date textbooks (MARSHAK & LINDNER ROBBINS 1959) suggest however that this conclusion may be erroneous. Many of the diseases of the small intestine accompanied by malabsorption are associated with marked disintegration of the medium in the ileum or even the jejunum; this has led to totally unrealistic mucosal coarsening and false patterns and as a result incorrect interpretation. Fig 6 indicates the apparent mucosal coarsening of a section of an intestinal loop several minutes after the suspension was disintegrated artificially. It is clear that continuous introduction of a large amount of contrast medium



Fig. 9. Early mucosal abnormalities in Crohn's disease easily differentiated in well filled case but difficult or impossible when the filling is moderate.

into the small intestine is only guaranteed when the function of the pylorus is eliminated and the medium is introduced directly into the duodenum by infusion.

Since most barium preparations on the market will withstand basic substances better than acid, the advantage of this method is that the detrimental effect of the mucin (FRAZER et coll. 1949) and gastric juice is avoided. The contrast medium must be hypotonic; hypertonicity stimulates secretion from the intestinal wall and an isotonic solution adversely affects closing of the pylorus. The addition of fats, proteins and carbohydrates may inhibit peristalsis and therefore delay gastric emptying, even with partial gastrectomy. Fewer peristaltic waves occur and the transit is retarded when the blood contains a high concentration of sugar and fats. On the other hand, a low concentration of these food substances in the blood may cause contraction of the stomach and a feeling of hunger. The diet must be of low residue for 24 hours before the examination, with the last meal fat free. It is also desirable that any medication that inhibits intestinal peristalsis should be withheld; stimulation of the production of gall or contraction of the gallbladder should also be avoided.

All these considerations suggested that the contrast medium should not be swallowed but should be introduced directly into the duodenum. Routine ra-



Fig 10



Fig 11



Fig 12

Fig 10 Abdominal survey after infusion of 600 ml contrast medium. In pelvis and obesity in particular the position of the loops of the small bow el is usually clear

Fig 11 No masking even after the administration of 1200 ml contrast medium

Fig 12 Loops of ileum freely separated by compression after introduction of 1200 ml contrast medium and 100 ml water

diologic examinations of the small bowel have been carried out by infusion for the past 3 years and more than 1500 patients have been examined. The rate of flow proved to be most effective when 600 ml medium were administered in 5 to 8 minutes: the caecum had already been reached by the end of the infusion period in 33 per cent of the patients and only several minute later or after a supplementary dosage of 300 ml medium or water in a further 33 per cent. The retarded transit in the remaining patients was caused by various factors: organic as well as functional. A supplementary dosage of 600 ml medium or water is



FIG. 13. Loops of ileum in true pelvis separated by compression after rectal and oral insufflation with air.



Fig 14



Fig 15

Fig 14 Abdominal survey after air insufflation through duodenal tube

Fig 15 A thin layer of barium covers the mucosa of the small intestine after the introduction through duodenal tube of 600 ml medium followed by 600 ml water

usually necessary for the caecum to be reached quickly. It has become apparent that a full ascending colon or treatment with drugs that produce intestinal atony are the most common causes of retarded passage. Thorough preparation of the patients is therefore exceedingly important. Another advantage of this is that after the examination of the small intestine it may be flushed with water enabling films to be obtained of the colon outlined with the contrast medium (Fig 7). even the double contrast technique may still be employed after the oral or rectal insufflation of air (Fig 8). It should be stressed that cleansing of the colon must be carried out by the oral route only and not by means of a rectal enema since many patients appear unable to empty the caecum completely after an enema. reflux of the crima into the caecum has also been known to occur. In addition to a marked retarding effect on the transit time in the ileum problems of interpretation arise due to the mixing of the enema with the medium flowing in from above. Also unfavourable for rapid transit through the small bowel is reduced peristaltic reflex in the duodenum caused by reflux of the medium into the stomach. This is almost always a result of an incorrect intubation technique or

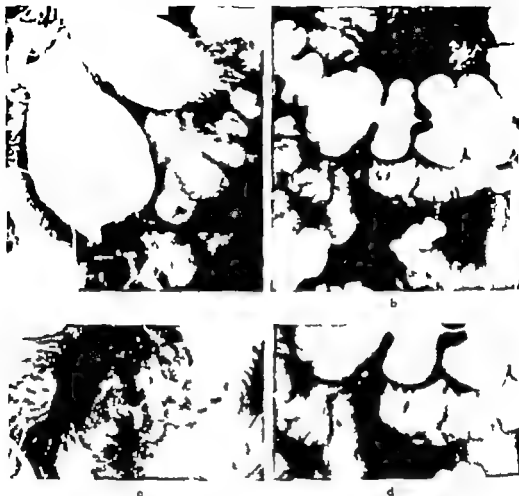


Fig. 16 Small reticulum cell sarcoma of small intestine evident with fusion technique (a). Rapid administration of contrast medium causing prestenotic dilatation (b). Detail of tumour (c). The tumour escaped notice in the conventional examination (b, d) although a large amount of medium (900 ml) was administered. No dilatation of the small intestine (b) detail of tumour area (d).

faulty positioning of the tube. Reflux may also sometimes result from either disturbed pyloric function due to drugs causing atony or too sharp an angle between the aorta and the superior mesenteric artery in highly emaciated patients.

The rapid administration of these larger amounts of contrast medium always enables the loops of the small intestine to be examined in a well filled state. A significant advantage of this is that small irregularities of the mucosa are less likely to be missed than when the same loops are slightly contracted (Fig. 9). An

attempt should therefore always be made to obtain films not only of the bowel when moderately filled but particularly when it is dilated, especially in the distal ileum where most abnormalities occur. The largest amounts of medium (max 1 200 ml) and water are necessary in paralytic ileus, ileus caused by obstruction, scleroderma and similar conditions. Up to 1 800 ml or more (max 2 400 ml) may then be necessary to reach the colon or the obstruction in 30 or 60 minutes or more.

Two extremely important factors that still fail to receive enough attention are the specific gravity of the contrast medium and the optimum exposure it demands. The specific gravity chosen is usually much too high and in addition the films are generally underexposed. An extensive series of experiments was performed with plastic tubes of varying diameter in a water phantom 20 cm thick. Barium suspensions of different specific gravity and wooden beads 5 to 12 mm in diameter were placed in the tubes. These experiments suggested that if the exposure technique is suitably adapted, the radiologic examination of the small intestine of a normal patient may best be carried out with a contrast medium of 1.25 specific gravity. This should be increased to 1.3 for an obese patient and decreased to 1.2 for a thin patient; a child of 4 to 8 years usually needs a specific gravity of 1.15 (SELLERS 1971). It is worthwhile noting that when the specific gravity of the contrast medium is properly chosen, 600 ml will never cause superposition of other intestinal loops (Fig. 10) and 1 200 ml will seldom do so (Fig. 11). Even with total fluid amounting to 1 800 or 2 400 ml it is still possible with adequate compression to project the separate loops freely (Fig. 12). If despite a prone-tilted position and a compression balloon between the lower part of the abdomen and the couch top it is still not possible to move loops of the ileum out of the pelvis, a supplementary insufflation of air rectally or orally may prove of value (Fig. 13). The inclusion of the double contrast technique with air (Fig. 14) or water (Fig. 15) may lengthen the duration of the examination by 5 or 10 minutes, but the roentgenograms obtained are quite often informative and usually justify the extra effort.

Discussion

Thickening of the barium suspension at the site of an obstruction in the small intestine has often been feared, although no case appears to have been reported. On the other hand it seems that the medium tends to become thinner in a dilated intestinal loop. Slight relative obstructions may also be demonstrated with the rapid infusion technique since prestenotic dilation is temporarily induced, something not possible with the oral administration of contrast medium (Fig. 16).

It is a misconception to assume that films that permit accurate anatomic eval-

uation of the small intestine can be obtained as long as the barium is introduced into the duodenum through a tube SCHATZKI (1943) LURA (1951) SCOTT HARDEN et coll (1961) and PROCTOR et coll (1960) also administered the medium directly into the duodenum although they failed sufficiently to consider the fact that a number of other equally important, requirements must also be satisfied if optimum films are to be obtained. It goes without saying that knowledge of the physiology of the small bowel is necessary for an understanding of the factors that have been mentioned. SCHATZKI and LURA were also handicapped because intubation was not always successful and usually required a great deal of time. SCOTT HARDEN and PROCTOR employed a somewhat better technique for intubation but the amount of contrast medium they introduced was much too low. Development of the Bilbao-Dotter tube (BILBAO et coll 1967) signified a great improvement: after some practice, the tube may be introduced in only a few minutes and can probably be handled by a nurse or radiographer.

It is however easier as well as safer to use the extended Bilbao tube now on the market: it can be inserted further—to the duodenum—and the feed line can never perforate the stomach through the tube openings. In order to avoid curling in the cardiac end of the stomach the tube must be swallowed with the patient sitting or standing: it is then manipulated until the end lies approximately in the pyloric antrum. The feed line is inserted: the patient then lies on the right side and under fluoroscopic supervision is directed to push the tube further himself. A flexible end 8 to 10 cm in length, makes the passage through the pyloric canal easier. With markedly ptotic stomachs the flexible end of the tube should be even longer: say 15 to 20 cm. Finally the tube is introduced further while the feed line is continuously pulled back until Treitz's ligament is reached. Visual control need be only intermittent and should be executed with a small field and a moderate roentgen dosage: after some practice it is usually possible to limit the exposure time during the introduction of the tube to 10 to 20 sec.

Conclusion

Radiologic examination of the small intestine by means of infusion with contrast medium would appear to save considerable time. In addition the information obtained is far superior to that achieved from conventional methods of examination: in fact for obstructions and the differential diagnosis of diseases accompanied by malabsorption it is the only choice since disintegration of the emulsion regardless of the brand no longer occurs. It would seem therefore that the oral administration of the medium, even by the MARSHALL method should be abandoned or at the most only employed in emergencies such as in mentally disturbed patients in whom intubation sometimes proves to be difficult.

SUMMARY

The radiologic examination of the small intestine would appear to be best performed by the technique of infusion following duodenal intubation. A material of over 1500 patients is reviewed and the method is described in detail and discussed. The procedure is far from new but has never been used on a large scale. Since duodenal intubation today takes only a few minutes the technique again deserves attention.

ZUSAMMENFASSUNG

Als beste Method für die Röntgenuntersuchung des Dünndarmes wird die Infusion von Barium durch eine Duodenalsonde empfohlen. Ein Material von 1500 Fällen wird mittels dieser Method untersucht dies wird detailliert beschrieben und besprochen. Obwohl die Methode keineswegs neu ist hat sie niemals Anwendung in diesem Massstab gefunden sie verdient besondere Beachtung da mit genügend Erfahrung nur wenige Minuten zu deren Ausübung benötigt werden.

RÉSUMÉ

L'examen radiologique de l'intestin grêle paraît être meilleur par la technique de l'injection après tubage duodénal. Une série de plus d 1500 Malades est passée en revue et cette méthode est décrite en détail et étudiée. Cette technique est loin d'être nouvelle mais elle n'a jamais été utilisée sur une large échelle. Étant donné que de nos jours le tubage duodénal ne prend que quelques minutes cette technique mérite maintenant l'attention.

REFERENCES

- BALBAO M. A., FRENCH L. H., DOTTER CH. T. and ROSEN J. Hypotonic duodenography. *Radiology* 89 (1967) 438.
- BRILCHMAN P. Over suspensies met baryumvulfaat. (In Dutch). *Pharm Weekbl* 49/50 (1947) 709.
- FRAZER A. C., FRENCH J. M. and THOMPSON M. B. Radiographic studies showing the induction of segmentation pattern in the small intestine in normal human subjects. *Brit. J. Radiol* 22/253 (1949) 123.
- GERSONY COHEN J. and SHAY H. Barium enteroclysis. A method for the direct immediate examination of the small intestine by single and double contrast technique. *Amer. J. Roentgenol* 42/3 (1959) 456.
- GOLDIE R. Radiologic examination of the small intestine. Second ed. J. B. Lippincott Philadelphia (1959).
- JAYE W. B. and HILKE R. Action of metoclopramide on gastric emptying and small bowel transit time. *Gut* 9 (1968) 200.
- LURA A. Radiology of the small intestine. Enema of the small intestine with special emphasis on the diagnosis of tumours. *Brit. J. Radiol* 24/281 (1951) 284.
- MARRIAR R. H. and LYNNER A. E. Radiology of the small intestine. W. B. Saunders Company Philadelphia (1970).

- MILLER R. E. and BRAHME F. Large amounts of orally administered barium for obstruction of the small intestine. *Surg. Gynec. Obstet.* 129/6 (1969) 1183.
- PANIDORF H. Die fraktionierte Duundarmfüllung und ihre klinische Bedeutung. *Fortschr. Röntgenstr.* 56 (1937) 627.
- PORCHER P. et CAROLI J. Un accélérateur maitend du transit intestinal (grêle et colon). *Arch. Mal. Appar. dig.* 46/7-8 (1957) 663.
- PYOOTT F., STREY D. F., SHELLSHAR M. F. and RHODES C. J. Radiological investigation of the small intestine by small bowel enema technique. *Gut* 1 (1960) 366.
- ROSENBERG L. L. *Golden's diagnostic radiology*. The Williams and Williams Company, Baltimore (1969).
- SCHATZKI R. Small intestinal enema. *Amer. J. Roentgenol.* 50/6 (1943) 743.
- SCOTT HARDEN W. G., HAMILTON H. A. II and Mc CALL SWITH S. Radiological investigation of the small intestine. *Gut* 2 (1961) 316.
- SELLINK J. L. Examination of the small intestine by means of duodenal intubation. (With an extensive bibliography.) H. E. Stenfort Kroese N. V. Leiden (1971).
- WEINTRAUB S. and WILLIAMS R. G. A rapid method of roentgenologic examination of the small intestine. *Amer. J. Roentgenol.* 61 (1949) 45.
- ZIVNER E. A. Radiology of the small intestine. Studies on contrast media for the examination of the gastro intestinal tract. *Brit. J. Radiol.* 24 (1951) 245.

INSTRUMENT FOR THE REMOVAL OF A GASTRIC BEZOAR

M H WHOLEY, E A ZILKA and M MANSOOR

Bezoar are not commonly encountered in gastroenterologic roentgenology. A survey of the literature indicates that trichobezoar usually occur in neurotic or mentally disturbed patients. On the other hand phytobezoar consisting of fibrous vegetable and fruit are encountered in otherwise ordinary patients. It is generally accepted that disturbance of gastric motility may often be an underlying factor as the incidence appears to be certainly more frequent after vagotomy and in patients with a history of gastric surgery (HARRIS & SZEVES 1971). However the reason for the foreign body is not always apparent and it may be reasonable to assume that anticholinergic drugs and antacids have some bearing (HARRIS & SZEVES).

A means has been obtained for the removal of gastric foreign bodies without surgery and was initiated by the presence of a bezoar 4 cm \times 5 cm \times 3 cm in size in a 35 year-old male physician. Gastroscopy was initially performed following roentgen examination in an attempt made to break up the bezoar. This procedure was unsuccessful and as the patient refused operation native was devised in a simple instrument constructed from ordinarily available in cardiovascular radiologic departments. Two 0.04 in. diameter of the cardiovascular type and 150 cm in length were passed into the stomach with the wire passing

Submitted for publication 7 May 1973



Fig 1



Fig 2

Fig 1 Bezoar in the basket in the oesophagus

Fig 2 Specimen in the basket

side holes and looped at the distal end of polythene tubing (ID 7 mm and 70 cm in length). The proximal ends were taped, as were the crossed loops, at the distal end, thus creating a basket by pushing and pulling the guide wires in the tube the size of the basket could be so reduced so as to enable it to be introduced into the stomach. A small amount of barium emulsion outlined the bezoar and minor manipulation enabled it to be slowly withdrawn with only minimal oesophageal discomfort. The entire procedure was accomplished in approximately thirty minutes with the patient able to take nourishment almost immediately afterwards. The examination was continuously controlled by TV fluoroscopy (Figs 1—3).

Discussion

This is a rare phenomenon although one that has been much discussed. The initial symptoms are usually vague while the signs of obstruction are typical due to the usual situation of the bezoar in the prepyloric area. Almost all bezoars are diagnosed by roentgenology except when they adhere to the stomach wall and are small in size (McKENNIE 1972).

This would appear to be the first report of the removal of a bezoar from the stomach under fluoroscopic control. It has been stated that the medical treat-

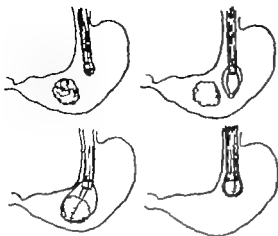


Fig 3 The instrument in the open and closed positions to manipulate the bezoar

ment of these bodies has been successful in a series of 4 patients (COHAN & STRZKA 1968). The present patient had had no operation and there was no history of any significant gastrointestinal symptoms: he had however eaten a large number of persimmon (date plums) about 6 weeks previously. Analysis of the mass confirmed that it was formed of vegetable fibres.

Although the treatment of bezoar by gastroscopy as well as by medical management has been reported before, it was felt that the introduction of this new method might be of some value: it appears to contain promise in those cases that cannot be managed by the traditional methods.

SUMMARY

A simple and effective method of removing foreign bodies from the oesophagus and stomach under TV fluoroscopy control is described, including its application in an adult male with phytobezoar in the stomach.

ZUSAMMENFASSUNG

Eine einfache und wirksame Methode für die Entfernung von Fremdkörpern aus dem Oesophagus und dem Magen unter fluoroskopischer Kontrolle wird angegeben. Die Anwendung der Methode im Fall eines erwachsenen Mannes wird als Beispiel angeführt.

RÉSUMÉ

Description d'une méthode simple et efficace d'extraction des corps étrangers du pharynx et de l'estomac sous contrôle de radioscopie télévisée y compris son application chez un homme adulte ayant un phytobezoar de l'estomac.

REFERENCES

- BILBAO M, KRIPPASINE W and DOTTER C. Catheter retrieval of foreign body from the gastrointestinal tract. *Amer J Roentgenol* 111 (1971) 473.
- CHIBA H and ISHIMAWA K. A Case of coffee bean treated with fiberoptic for biopsy. *Stom Intest (Tokyo)* 5 (1970) 81.
- COHEN N V and STRIKA Z A. The medical treatment of bezoars. *Gastrointest Endosc* 14 (1968) 144.
- DOTTER C, ROSEN J and BILBAO M. Transluminal extraction of catheter and guide fragments from the heart and great vessels. 29 collected cases. *Amer J Roentgenol* 111 (1971) 467.
- KIRAL D and SZELES G. Autolysis and gastric bezoar. A case report. *Gastroenterology* 61 (1971) 96.
- KOGA M. On bezoars in Japan. *Stom Intest (Tokyo)* 4 (1969) 575.
- McLEICHTER J. Gastroscopic removal of a phytobezoar. *Gastroenterology* 62 (1972) 1047.

THE VESTIBULAR AQUEDUCT AND THE PARA VESTIBULAR CANAL

An anatomic and roentgenologic investigation

H F WILBRAND, H RASK ANDERSEN and D GILSTRÖM

Advanced oto surgery in cases of Meniere's disease has initiated preoperative tomography of the temporal bone (CLEMIS & VALVASSORI 1968, BRUYER & PEDERSEN 1971, SERANA et coll 1971, WILBRAND 1971, BISCH & BARRIONUEVO 1972).

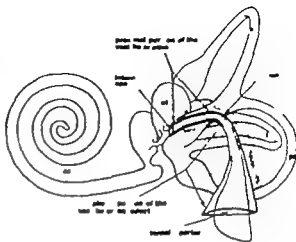
The membranous labyrinth with the cochlear and vestibular receptor organs has contact with the posterior fossa by the endolymphatic duct in the vestibular aqueduct (Fig 1). The endolymphatic duct ends with a blind sac (sacculus endolymphaticus) on the cerebellar surface of the pyramid between two sheets of the dura. Much interest has been focused on the duct and sac in investigations of the aetiology and treatment of Meniere's disease.

Extensive anatomic and embryologic examinations of the inner ear have been reported by BAST & ANSON (1949) and ANSON et coll (1965, 1967, 1968) primarily as a basis for surgery.

Additional measurements have been performed by OGURA & CLEMIS (1971) who have also demonstrated a para vestibular bone channel, running from the vestibule to the posterior fossa close to the vestibular aqueduct.

From the Department of Diagnostic Radiology, Akademiska Sjukhuset and the Department of Human Anatomy, University of Uppsala, S-750 14 Uppsala, Sweden. Submitted for publication 27 November 1973.

Fig 1 The membranous labyrinth and the vestibular aqueduct. The aqueduct originates from the medial wall of the vestibule as a bony canal for the endolymphatic duct and as the external periphery of the aqueduct is located on the cerebellar surface of the pyramid. sc—superior semicircular canal; lc—lateral semicircular canal; pc—posterior semicircular canal; cc—crus commune; t—tricleus; sc—sacculus.



A comparative anatomic and tomographic investigation of the vestibular aqueduct has been carried out by BISCH & BARRIONOVA (1972).

Proposed tomographic projections and the understanding of the possibilities of demonstrating the vestibular aqueduct have previously been based on limited experience. In the present investigation tomography and subsequent microdissections of specimens have been performed and the results compared with the aim of providing a reliable basis for clinical tomography. A further purpose was to collect additional anatomical evidence of the existence of the paravestibular canal previously demonstrated by OOURA & CLEVIS on microdissection; its importance is not yet fully understood.

Anatomy

The vestibular aqueduct (Fig 1) forms a bony channel for the endolymphatic duct on its way from the vestibule of the inner ear to the cerebellar surface of the pyramid. The aqueduct originates in the medial wall of the vestibule from a furrow (Fig 2) that gradually deepens to form its vestibular aperture and continues as a bony channel through the otic capsule, immediately in front of and somewhat medial to the crus commune of the superior and posterior semicircular canals (Figs 1, 2, 3, 4). The first portion of the aqueduct has the same direction as the crus commune and follows its course to at least half the length of the crus or somewhat further to its division into the superior and posterior semicircular canals. The aqueduct then bends, forming a more or less marked angle, to continue its course under the bony plate of the cerebellar surface of the pyramid (Fig 3). The proximal portion of the aqueduct up to the bend

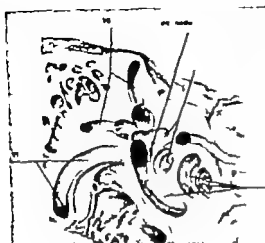


Fig. 2

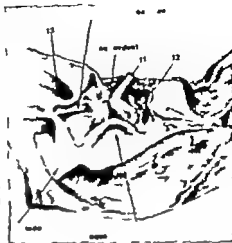


Fig. 3

Fig. 2 Internal picture of the vestibular aqueduct seen from inside the vestibule (redrawn and modified after PEARSON 1960) 10—facial nerve canal region of the lateral knee 10—lateral semicircular canal 11—superior semicircular canal Ac—area cribiformis trinch Cr—crusta vestibuli Ac—area cribiformis macularis Sa b c—cochlea

Fig. 3 Vestibular aqueduct seen from the posterior fossa. The vestibule and cochlear aqueducts have been exposed by means of dental drill. For topographic purposes, borders of bone was spared at the pore of the external aperture of the vestibular aqueduct 11—superior semicircular canal 1—posterior semicircular canal 12—internal acoustic meatus

(isthmus) is narrow. The peripheral portion gradually widens on its course to the cerebellar surface of the pyramid where it opens into the posterior cranial fossa as a slit like fissure, the external aperture. This is easily recognized about 10 mm postero-lateral to the opening of the internal acoustic meatus and 10 mm inferior to the superior petrosal sulcus (ANSON et coll 1965, 1968). The endolymphatic duct opens into the endolymphatic sac which is partly situated in the aqueduct with its pars rugosa and partly continues between two sheets of the dura outside the external aperture close to the sigmoid sinus.

The endolymphatic duct on its way through the vestibular aqueduct is surrounded by loose connective tissue containing blood vessels which are especially abundant in the wider peripheral portion of the aqueduct with the pars rugosa. There is no report that any major artery passes along with the endolymphatic duct through the aqueduct.

The venous drainage of the labyrinth takes place partly through the vein of the vestibular aqueduct draining blood from the semicircular canals and the utricle. This vein passes from the vestibule with the endolymphatic duct through the vestibular aqueduct, penetrates the dura and opens into the sigmoid sinus. Just before the sinus it receives numerous small veins from the rich venous plexus

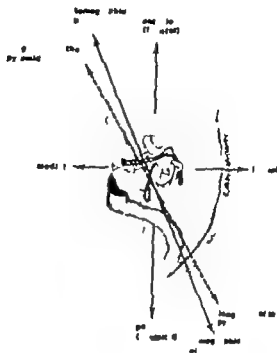


Fig. 4. Orientation of the labyrinth in the axial view. The course of the vestibular aqueduct is nearly parallel to the sagittal plane. Tomographic plane as applied in tomography of the specimens. The facial nerve is seen in its relationship to the cochlear and vestibular parts of the membranous labyrinth.

around the endolymphatic sac (BAST & ANSON 1949). Vascular variations occur, however (WOLFF *et coll.* 1957, KELLNER & RICHTER 1962, ANSON *et coll.* 1963, 1968).

Histologically, ANSON *et coll.* (1963, 1968) revealed the existence of vascular channels in close connection to the vestibular aqueduct, and OOURA & CLEWIS observed both an artery and a vein in the paravestibular bone canal.

Material. Thirty-five temporal bone specimens obtained from non-selected autopsy cases (22 male and 13 female individuals of ages 5 to 75 years, mean 56 years, in 9 cases bilateral) were examined.

Methods. The specimens were mounted on a plexiglass holder with the intention of simulating clinical positioning (Fig. 5). It was found difficult, however, to position the isolated temporal bone correctly without it being in reference to other skull structures.

Tomography was performed with a Polytome, using its hypocycloid movement and with a magnification factor of 1.3, focus size 0.3 mm, exposure data 50 to 55 kV, 50 mA, 5.8 s (one hypocycloid movement), high definition screens (Siemens Rubin) and RPL film processed in a 90 s Pakoral machine at 35 °C.

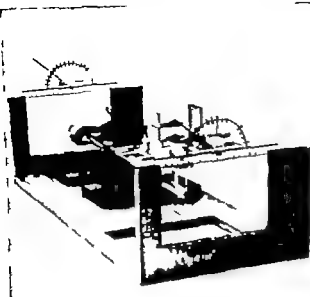


Fig. 5 Plexiglas holder for tomography of the temporal bone specimens

The specimens were tomographed at an inclination of 20 to 25° from the lateral projection towards the long axis of the pyramid (Fig. 4) which meant that the tomographic plane in the pyramid was at an angle of 20 to 25° to the sagittal plane. The distance between the cuts was 0.5 mm to guarantee overlapping of information contents from one tomogram to the next.

Measurements were carried out with a vernier caliper (division 1/10 mm) under optimal viewing conditions, i.e. carefully shaded viewing of each tomogram in a 6-seriogram by means of a mask with a density of 1.5 to 1.8 at the ordinary viewing box and subdued illumination of the environment (ROTTLER 1967).

The distance from the internal aperture of the aqueduct to the bend and the distance from the bend to the external aperture were assessed by three viewers independently on repeated occasions. Exact assessment of measurement points at the external aperture was difficult in some cases and to a lesser degree also at the internal aperture due to low contrast.

After tomography the specimen was stained with 4% O_2O_4 solution in a phosphate buffer which was injected through the oval window and the external aperture of the aqueduct. Staining provided guidance on drilling. Under a dissection microscope bone tissue was removed with a dental burr to expose the vestibular aqueduct. The otic capsule of the superior and posterior semicircular canals was saved (Figs 6, 7). The course of even very gracile para vestibular canals could be followed. These canals and the aqueduct were carefully opened. At the external aperture a small bone bridge (operculum) was saved for mea-



Fig. 6. Dissected temporal bone. The vestibular aqueduct (av 1 and av 2) and the para-vestibular canal (pa) from the medial aspect. The exposed aqueduct exhibits relatively straight course through the pyramid with a reciprocal widening of the peripheral part (av 2). For topographic purpose bridge of bone was saved at the external perture (pt ext). The para-vestibular canal is visible medially and below the aqueduct with small channel (ch) communicating with the aqueduct in the immediate vicinity of the crus commune. The peripheral mouth of the para-vestibular canal is located in the immediate vicinity of the external perture of the aqueduct. Wide angle between the proximal (av 1) and peripheral parts (av 2) of the vestibular aqueduct. The internal acoustic meatus (ma) exposed demonstrating the transverse crest subdividing the lateral fundus of the meatus.



Fig. 7. Dissected temporal bone. The vestibular aqueduct (av 1 and av 2) from the occipital aspect. The proximal part (av 1) runs fairly parallel to the crus commune. At the bend (isthmus) the diameter of the aqueduct is small (0.1 mm) subsequently slight widening of the peripheral part (av 2). A bridge of bone was saved at the external perture (pt ext). The para-vestibular canal is situated beneath the aqueduct (not visible in the photograph). The superior (sc) and the posterior (pc) semicircular canals are imagined running from the crus commune in the rear of the proximal part (av 1) and the isthmus of the aqueduct. Small angle between the proximal and peripheral parts of the aqueduct (compare with Fig. 6). ma—internal acoustic meatus.

TABLE 1

Results of measurements of the vestibular aqueduct in tomographs of isolated human temporal bone specimens

	Mean value mm	Range mm	Standard deviation mm SD	Number of observations
Total length series 1	8.20	5.7-11.0	1.47	33
Total length series 2	8.05	5.5-10.1	1.33	35
Total length series 3	8.06	5.4-11.8	1.44	35
Total length all observations	8.10	5.4-11.8	1.28	103

TABLE 2

Results of measurements of vestibular aqueducts in dissected human temporal bone preparations

	Mean value mm	Range mm	Standard deviation mm SD	Number of observations
Total length of the aqueduct	8.47	6.1-12.6	1.34	35
Length of the proximal portion of the aqueduct	2.1	1.2-3.0	0.60	35
Length of the peripheral portion of the aqueduct	6.30	4.0-9.9	1.35	3
Width of the internal aperture	0.67	0.4-1.0	0.17	3
Smallest width of the aqueduct	0.2	0.1-0.4	0.09	14
Height of the external aperture	0.8	0.2-1.4	0.27	34
Breadth of the external aperture	6.46	3.1-15.0	2.35	35

measurement of the height and width of this aperture. The flat triangular widening of the peripheral portion of the aqueduct was saved for assessing variations of its shape in different temporal bones.

Measurements of the stained specimens were performed on different occasions by means of an optic scale (1/10 mm) in the dissection microscope.

For assessment of variations of the course of the aqueduct in relation to the superior semicircular canal the specimens were photographed in the vertical direction. In enlarged photographs variations of an inherent lateral curving of the aqueduct could be assessed. The angle between the proximal and peripheral portions of the aqueduct was estimated with the aid of simple optic enlargement and a square rule.

Results

Measurements on tomograms The mean total length of the vestibular aqueduct was 8.1 mm (range 5.4 to 11.8, SD 1.28). The differences between the three viewers' results of iterated measurements were very small (Table 1). The total length of the aqueduct is composed of the sum of the length of the proximal portion—the distance from the internal aperture to the bend (isthmus) of the aqueduct—and that of the peripheral portion—the distance from the external aperture to the isthmus. The measurement point at the bend was represented by its vertex situated at the mid height of the crus commune or somewhat higher up towards its division into the superior and posterior semicircular canals. The values obtained for the proximal and peripheral portions of the aqueduct are not specified in Table 1 owing to difficulties in defining the measurement point exactly at the bend in cases where this was more like a curve than an angle. The measurement point at the external aperture was the tip of the bone bridge (operculum) overhanging this aperture. The measurement values in the films were reduced to natural size (the tomographic magnification factor was 1.3).

The entire aqueduct was observed in 51 per cent of the cases; that part of the aqueduct which could not always be identified was the proximal portion or the isthmus. A para vestibular bone canal could be discerned in 7 of the 95 cases (20 per cent) (Fig. 9c).

Measurements on specimens The results of direct measurements on the specimens are presented in Table 2. The measurements revealed that the total length of the aqueduct is mainly influenced by the length of the peripheral part (correlation coefficient: total length—peripheral part 0.91, highly significant; total length—proximal part 0.45, significant). The mean length of the proximal part was 2.15 mm and that of the peripheral part 6.3 mm. The mean total length of the aqueduct was 8.47 mm (Table 2). The internal aperture could not be measured from the vestibule, as has been done by other authors (ANSOY *et al.* 1965, 1968; OOURA & CLEVERIS 1971), instead following the proximal part of the opened aqueduct in the direction towards the vestibule, at the mouth of which a thin bone shell was preserved, the diameter of the mouth was measured. This procedure might have influenced the objectivity of the measurement in view of the difficulties in finding the correct anatomic measurement points.

The location of the narrowest part of the aqueduct varies but it lies at or in the vicinity of the bend.

Exact measurement of the external aperture is difficult owing to its irregular shape. In the present material its height is given as the mean value of the longest vertical distance.

Table 3

Additional observations and results of direct measurements of the vestibular aqueduct and para vestibular canal in human temporal bone specimens

Angle between proximal and peripheral portion of the aqueduct	90-135
Lateral curving of the aqueduct	9/35 (26 %)
Recess like widening of the peripheral portion of the aqueduct	11/35 (31 %)
Para vestibular canal observed in dissection	35/35 (100 %)
Para vestibular canal localized lateral to the aqueduct	9/35 (26 %)
Mean width of para vestibular canal	0.12 mm (range 0.1-0.2)

Additional observations and anatomic measurements of aqueducts and para vestibular canals are presented in Table 3. In the anatomic preparations the angle between the proximal and peripheral portions of the aqueduct was 90 to 135°. Generally speaking it seems as if long aqueducts have a smaller angle between the proximal and peripheral portion and vice versa (Figs 6-7).

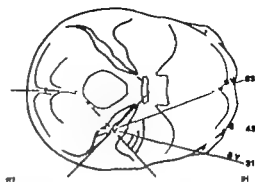
A laterally curved deviation of the aqueduct from its otherwise straight course through the pyramid (viewed in the axial projection) in relation to the superior semicircular canal could be observed in 9 of the 35 specimens (26 per cent).

The width of the aqueduct increases from the isthmus to the external aperture with considerable variations from case to case (Figs 3-6-7). The bony wall of the flat peripheral portion may be irregular with clearly discernible furrows and often canalicular openings. Similar but less evident irregularities may also occur in narrower portions of the aqueduct. The peripheral portion may occasionally be narrow with only a hint of a triangular widening (Fig. 7).

The width of the external aperture (mean value 0.46 mm) was related to the length of the peripheral portion of the aqueduct (correlation coefficient 0.47, significant); the longer the peripheral portion of the aqueduct the greater the width of the external aperture. The peripheral portion usually appeared as a regularly flat triangular widening which however sometimes extended laterally forming a pouch or recess (Fig. 6). Such appearances were observed in 11 of the 35 specimens (31 per cent).

Close to the aqueduct a para vestibular canal was observed in every specimen (Figs 6-11, Table 3). It ran at a short distance medial to and somewhat

Fig. 11 Orientation of the vestibular aqueduct reference to the superior semicircular canal in the skull base. The mean inclination of the vestibular aqueduct (α) is 45° (range 31° — 65°) reference to the plane of the superior semicircular canal (ssc). On the assumption that the superior semicircular canal is located perpendicularly to the longitudinal axis of the pyramid, the inclination of 45° to the sagittal plane of the skull base, the course of the vestibular aqueduct is on the average parallel to the film plane in the true lateral projection.



beneath the aqueduct through the temporal bone from the vestibular wall to the external aperture where it had a separate opening. The width of the canal varied between 0.1 and 0.2 mm (mean value 0.12 mm).

In two cases a duplicate canal could be seen originating from the vestibule communicating with the aqueduct and joining near the external aperture. In some cases the peripheral portion of the paravestibular canal emerged into the floor of the external aperture near the foveate impression for the endolymphatic sac.

The paravestibular canal was localized lateral to the aqueduct in 9 of the 35 specimens (26 per cent) (Table 3). In 2 only the peripheral part was observed and thus followed the peripheral portion of the aqueduct on its lateral side; the proximal parts were assumed to run directly beneath the aqueduct and for technical reasons could not be explored by dissection. In these two cases the canal had its orifice on the lateral side of the external aperture.

The paravestibular canal in one specimen ran adjacent to the aqueduct in its proximal part but diverged at the bend and emerged in close proximity to the external aperture. In a few specimens openings of vascular canals were evident in the wall of the peripheral, triangular part of the aqueduct.

Comparison between measurements on tomograms and on temporal bone specimens. The measurements on the tomograms and on the dissected temporal bone specimens showed good agreement (correlation coefficient 0.55) (Fig. 10). The mean of the total length of the aqueduct on tomograms for all three views was 8.1 mm while that on specimens was 8.47 mm. An aqueduct with a diameter of 0.1 mm measured on a dissected specimen could be discerned in the tomogram (Fig. 9a).

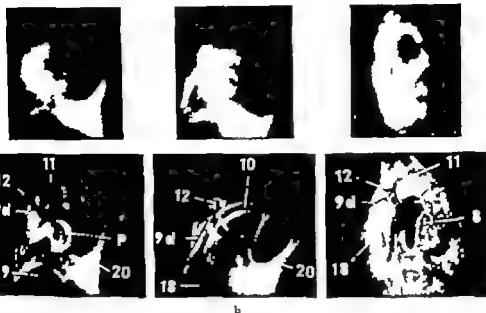


Fig 9 Tomograms of the vestibular aqueduct (projection see Fig 4) a) Tomographic reproduction of small vestibular aqueduct is anatomy exposed by dental drill in Fig 7 The specimen represents anatomy of the vestibular aqueduct with narrow proximal part (Measurements on microdissection narrowest width 1.1 mm immediately peripheral to the bend of the aqueduct length of the proximal part of the aqueduct 1.7 mm length of the peripheral part 9.9 mm breadth of the external aperture 1.7 mm width of the internal aperture 0.4 mm angle between proximal and peripheral parts 90° plane of the aqueduct 33° in reference to the plane of the superior semicircular canal) b) Tomographic reproduction of the specimen in Fig 6 Short wide aqueduct and discernible para vestibular canal beneath the aqueduct (Measurements on microdissection narrowest width of the aqueduct 0.25 mm at the bend Length of the proximal part 3 mm peripheral part 5.6 mm recess-like indentation of the peripheral part Breadth of the external aperture 6.5 mm width of the internal aperture 0.8 mm angle between proximal and peripheral portions of the aqueduct 130° plane of the aqueduct 50° in reference to the plane of the superior semicircular canal) 10—external aperture 11—superior semicircular canal 12—angle between proximal and peripheral parts 13—plane of the aqueduct 14—plane of the superior semicircular canal 15—vestibular aqueduct 16—cochlear coils 17—anterior structures of the lateral semicircular canal 18—superior semicircular canal 19—sigmoid sinus 20—jugular vein P—tympanic bone

Discussion

Previous reports on tomography of the vestibular aqueduct (JUSTER & FISCH GOLD 1955 AGAZZI et coll 1958 CLEMIS & VALVASSORI 1968 BRUNNER & PEDERSEN 1971 SAWADA et coll 1971 WILBRAND 1971 BISCH & BARRIONUEVO 1972) have discussed positioning for demonstration of this structure. Insertion of a metal thread into the aqueduct (CLEMIS & VALVASSORI BRUNNER & PEDERSEN) and injection of small quantities of contrast medium into it served as aids for demonstrating its course through the pyramid BISCH & BARRIONUEVO examined 50 temporal bone specimens in order to assess morphologic variations

Table 4

Measurements of the vestibular aqueduct at macrodissection. Comparison of results obtained by different authors

	ANDON <i>et al.</i> (1963, 1968)	OGURA & CLEMIS (1971)	Present investigation
Width of the internal peritum	0.35 mm (0.25–0.50)	0.3 mm (0.2–0.6)	0.6 mm (0.4–1.0) SD 0.17
Width of the aqueduct at the isthmus	0.3 mm (narrowest 0.17)	0.3 mm (0.2–0.4)	0.24 mm (0.1–0.4) SD 0.1
Total length	8.5 mm	8.7 mm (5.0–12.0)	8.47 mm (6.1–11.6) SD 1.54
Length of the proximal portion		1.4 mm (1.0–1.9)	2.2 mm (1.1–3.0) SD 0.6
Length of the peripheral portion		7.3 mm (4.0–10.0)	6.3 mm (4.0–9.6) SD 1.3
Width of the external peritum	7 mm (1.0–13.0)	6.2 mm (3.0–9.0)	6.5 mm (3.1–11.0) SD 2.35
Height of the external peritum	0.3 mm		0.6 mm (0.1–1.4) SD 0.3

in the course of the aqueduct but were unable to demonstrate its proximal portion tomographically. There is no comment on the radiographic system and technique used except that the Polytome with its hypocycloid movement was employed and that a focal size of 0.6 mm was used.

The examinations of CLEMIS & VALVASSORI on patients were performed on the Polytome but it is not clear from their report to what extent a focal spot of 0.3 or 0.6 mm and different projections were used. The distance between the cuts was 0.5 to 1 mm. The authors considered that the failure to demonstrate the aqueduct in their material of Meniere's disease was not due to technical factors.

Visual perception of delicate structures in tomograms is dependent not only on their dimension but also to a high degree on their shape. The length and course of the aqueduct on tomograms and in dissected specimens were therefore compared to evaluate the reliability of the tomographic image. This comparison

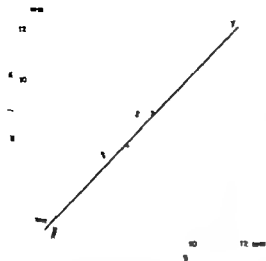


Fig 10 Comparison of measurements of the vestibular aqueduct (total length) in 33 fresh human temporal bone specimens on dissection and in their tomograms. The reduced values (tomographic enlargement factor 1.3) from the tomograms are in general smaller than the dimensions in the anatomic specimens.

showed good agreement. The individual results of the three viewers differed only slightly. A comparison between the results obtained in this material and measurements reported by ANSOV *et coll* (1965, 1968) and OGURA & CLEMIS (1971) also showed good agreement on the whole (Table 4).

The mean length of the proximal portion of the aqueduct was 0.8 mm greater in our material than in that of OGURA & CLEMIS and the length of the peripheral portion 1 mm shorter. The vertex of the bend (isthmus) of the aqueduct serving as measuring point in both investigations. The position of this vertex was sometimes difficult to assess and the three viewers did not always agree except in cases where it consisted of an obvious angle between the proximal and peripheral portions of the aqueduct.

The mean width of the internal aperture of the aqueduct has been found by ANSOV *et coll* (1965) to be 0.35 mm. On specimens OGURA & CLEMIS (1971) made measurements of this aperture from the inside of the vestibule in two dimensions: the vertical diameter having a mean value of 0.3 mm (0.2 to 0.6) and the horizontal diameter 0.2 mm (0.2 to 0.4). ANSOV *et coll* do not specify their procedure but their results are in good agreement with those of the former authors. The mean value of 0.6 mm (0.4 to 1.0) obtained in the present material is based on a different method of measurement which may explain the discrepancy.

The shape of the external aperture of the aqueduct varied extensively but the values in the present material are nevertheless in good agreement with those of the authors mentioned (Table 4).

The angle between the proximal and peripheral portions of the aqueduct

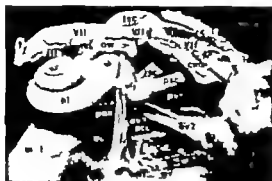


Fig. 11. Plastic mould of the inner ear revealing the delicate structures of the aqueduct and the para-estibular canal from the vestibule to the posterior surface of the pyramid seen from below. *av* 1—proximal part of the vestibular aqueduct; *av* 2—peripheral part of the aqueduct; *pc*—para-estibular canal; *ac*—cochlear aqueduct; *pc*—para-cochlear canal; *ma*—internal acoustic meatus; *pa*—posterior ampullary nerve canal; *lc*—lateral semicircular canal; *VII*—tympanic portion of the facial canal; *VIIb*—site of the geniculate ganglion; *cr*—canal for the stapedius muscle; *VIIc* and *VIIe*—lateral knee and rounded part of the facial canal; *rw*—round window; *ow*—oval window; *cc*—canaliculus chorda tympani; *VII*—foramen stylomastoidium.

varied between 90° and 135° and had a negative correlation with the aqueductal length (correlation coefficient = -0.3409) the shorter the aqueduct the wider the angle. In early foetal life the aqueduct has a fairly straight course its proximal part running parallel and somewhat postero-medially to the crus commune and the peripheral part in a posterolateral direction emerging with the same orientation into the posterior fossa (BAST & ANSON 1949). In the later half of foetal life when the inner ear has finished its growth but when the brain and the skeleton in the environment of the inner ear are still growing and the pneumatization of the temporal bone is taking place, the original straight course changes. The peripheral part of the aqueduct and the angle between the proximal and peripheral portions achieve their final shape and the final dimensions of the different parts and the total length of the aqueduct are attained.

The peripheral part of the aqueduct had a laterally curved course in 9 of the 35 cases (26 per cent). Such a curve as well as variations of the angle between the proximal and peripheral parts are mentioned by OOURA & CLEVIS (1971). The curve may be an expression of growth dynamics. The same applies to the development of the external aperture, with its great variety which is obviously dependent upon growth factors in the posterior fossa (ANSON *et al.* 1965, 1968).

The pars rugosa of the endolymphatic sac situated in the peripheral triangular portion of the aqueduct takes a highly active part in the metabolism of the endolymphatic system (LUNDQVIST 1965). In this material the mean width of the external aperture slightly exceeded the mean length of the peripheral portion

This implies that a long aqueduct provides a wider space for the endolymphatic sac than a short one. The shallow recess at the peripheral part of the aqueduct was seen in 11 of the 35 specimens (31 per cent) (Fig. 6). The wider this recess, the larger the space for the pars rugosa of the endolymphatic sac.

An optimal reproduction of the aqueduct implies demonstration of its entire course from the internal to the external aperture in one single tomogram. The width of the flat triangular peripheral portion of the aqueduct can be estimated from a consecutive series of cuts. Thus the peripheral part may be assessed pre-operatively with a fair degree of accuracy. This may be valuable in the planning of shunt operations for Ménière's disease.

The aqueduct generally ran in one plane in the pyramid. An exception was seen in 9 of the 35 cases (26 per cent) where the peripheral portion curved laterally. The plane of the vestibular aqueduct varied in general between 31 and 65° in reference to the plane of the superior semicircular canal (Fig. 8). The latter plane is generally said to be at right angles to the long axis of the pyramid and to have a mean inclination of 45° to the sagittal plane of the skull (SOBOTTA 1952; PERNAOFF 1960; ROHEV 1971; JENSEN 1972). On the basis of this relationship a common course of the aqueduct and its variations have been depicted in a schematic drawing of the skull base in Fig. 8 which illustrates the most suitable projection in which the aqueduct can be expected to be properly reproduced in tomograms. If it is not fully demonstrated in the true lateral view additional projections are necessary (Fig. 12). If the aqueduct is smaller and also curves laterally in relation to the superior semicircular canal fundamental difficulties may arise in the tomographic reproduction. Furthermore the longitudinal axis of the pyramid does not always follow the direction generally accepted to be 45° to the sagittal plane. This means that the geometrical distribution of the superior semicircular canal in relation to other structures of the skull base is not constant (SCHÖNEMANN 1906). CLEMIS & VALVASSORI (1968) recommended a lateral or slightly modified lateral projection for demonstration of the aqueduct. BRUNYER & PEDERSEN (1971) advocated similar positioning under visual control with a TV monitor. The measurements on the specimens are in agreement with the statement by CLEMIS & VALVASSORI that the plane of the aqueduct is at a mean inclination of 45° to the longitudinal axis of the pyramid. The tomographic plane used in this investigation thus proved not to be ideal and may explain the fact that the aqueduct was not demonstrated in a higher percentage of specimens. Another possible source of failure is undue rotation of the isolated specimens. The measurements on dissected temporal bones revealed that the plane of the aqueduct varied by about 15° to the one direction and 20° to the other from the mean value of 45°. This may be of fundamental importance as such variations may give rise to unsatisfactory demonstration of the entire aqueduct in one

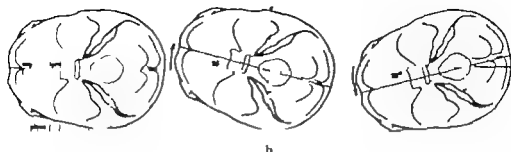


Fig. 12 Positioning in tomography of the vestibular aqueduct. (a) True lateral (b) Complementary positioning in cases of unsatisfactory demonstration of the aqueduct in the true lateral projection.

projection (EDHOLM 1960 STRYVE 1972). In such cases the projection must be altered 15° to either side from the true lateral projection (Figs 11, 12). In the present material 9 (26 per cent) of the aqueducts had a course through the pyramid beyond a 10° variation from the mean inclination of 45°. There are no means of screening, as the semicircular canals and the aqueduct cannot satisfactorily be discerned in axial views. In tomograms the true lateral projection primarily gave the best survey of the aqueduct.

In tomograms the paravestibular canal was observed in only 7 of 35 temporal bones (20 per cent) but at microdissection it was regularly present. OGURA & CLEMIS on dissection of 23 temporal bone specimens found 12 clear canaliculi. 3 others were only partially observed while in 8 cases no channel was found at all. The authors assumed that failure to demonstrate the channel may have been due to technical factors in the microdissection, a failure of the staining capabilities or its true absence. In the present material the channel was always revealed in the preparations and only with an anatomically divergent course did preparatory difficulties arise which do not make its regular existence questionable.

The interrelationship between the paravestibular channel and the aqueduct was first discussed by OGURA & CLEMIS. ANDERSON *et al.* (1965, 1968) have mentioned the existence of small vascular channels along the course of the vestibular aqueduct conveying vessels to and from the connective tissue around the endolymphatic duct and sac. However they have not claimed the existence of a regular channel which by histology (OGURA & CLEMIS) has been found to contain both an artery and a vein supported in loose connective tissue. The present investigation has proved the regular existence of a paravestibular canal with some typical variations in its course alongside the aqueduct. The connection between this channel and the contents of the vestibular aqueduct is obvious, as small vessels pass from the paravestibular canal to the aqueduct and

by its peripheral opening in close vicinity of the external aperture or directly into it (Figs 6-11). The fact that the lumen, although its width varied between 0.1 and 0.2 mm, could be demonstrated in tomograms of several specimens indicates that with the radiographic system used and under optimal viewing conditions visual perception of such structures may be possible.

The failure to demonstrate the entire aqueduct in 49 per cent of the specimens in this material was probably due mainly to inadequate positioning but may also have been caused by extreme variations in the course of the aqueduct. Visual perception of delicate structures with low image contrast may also be discussed as a matter of psychologic influence. For that reason repeated measurements and evaluations of tomograms were performed on several viewing occasions. A statement of visibility was based in every case on an unanimous decision by all three viewers that the entire aqueduct was visible on every viewing occasion.

Conclusion

Progress in otosurgery has increased the demands for preoperative roentgenographic demonstration of the vestibular aqueduct. Its anatomy has been incompletely known hitherto. An investigation consisting of tomography and microdissection of temporal bone specimens has therefore been performed.

The measurements on dissected temporal bone specimens confirmed the results of previous anatomic and histologic investigations concerning the length and width of the aqueduct and its course. A recess like previously unreported widening of the peripheral part of the aqueduct was observed in 1/3 of the cases.

Microdissection revealed that a para vestibular canal is present in every temporal bone. It has a diameter of 0.1 to 0.2 mm. Its topographic relationship to the endolymphatic sac opens up a new aspect of the vascularization of this structure.

Tomography of the specimens proved the reliability of measurements on tomograms as compared with measurements on dissected specimens, a prerequisite for metric evaluation of tomograms in preoperative assessments of the aqueductal morphology.

The demonstration of the aqueduct depends on very correct positioning. For clinical examination an initial true lateral position is recommended. If this gives an unsatisfactory result complementary projections with a 15° inclination on either side from the true lateral projection might be used before a final appraisal is made.

With a proper technique and under optimal viewing conditions the entire length of the aqueduct can be observed even when its narrowest luminal diameter is only 0.1 to 0.2 mm. Thus failure to demonstrate the aqueduct can be regarded as being primarily due to inadequate positioning or anatomic variation.

The para vestibular canal had a diameter of 0.1 to 0.2 mm and was tomographically demonstrated in 7 of 35 (20 per cent) specimens.

Computer processing of measurements on specimens and tomograms showed interrelationship between the dimensions of the aqueductal structures.

SUMMARY

A comparative investigation of the anatomy as revealed by microdissection and the multidirectional tomographic features of the vestibular aqueduct was performed in fresh isolated temporal bone specimens. Evidence was obtained of the reliability of analysis and measurements of the aqueduct on tomograms. The investigation elucidated the anatomical anatomy of the vestibular aqueduct and its importance in the tomographic demonstration of this structure which with otosurgical advances is becoming an increasing preoperative necessity. Further evidence of the existence of a para vestibular canal and its association with the vestibular aqueduct was produced.

ZUSAMMENFASSUNG

In einer anatomischen und tomographischen Untersuchung frischer isolierter Felsenbeine wurde die Morphologie des Aqueductus vestibuli dargestellt. Dabei erwies sich, dass bei entsprechender Technik tomographische Analyse und Messresultate als zuverlässig bewertet werden können. Weiterhin wurden die anatomischen Variationen des Aquaduktes und ihre Bedeutung für die tomographische Darstellbarkeit dieser Struktur klargestellt, welche bei einer Otorrhinotomie zu einer nützlichen präoperativen Massnahme geworden ist. Zudem kommt der Beweis der Existenz eines para-vestibulären Canalculus und dessen Zordnung zum Aqueductus vestibuli geliefert werden.

RÉSUMÉ

Les auteurs ont fait une étude comparative de l'anatomie de l'aqueduc du vestibule examinée par microdissection et de ses images par tomographie multidirectionnelle sur des os temporaux frais isolés. Ils ont établi la fiabilité de l'analyse et des mesures de l'aqueduc sur les tomographies. Cette recherche précise les variations anatomiques de l'aqueduc du vestibule et leur importance pour la mise en évidence tomographique de cette structure qui devient un examen pré-opératoire de plus en plus nécessaire en raison des progrès de l'otologie. Ce travail a fourni une nouvelle preuve de l'existence d'un canalicule para-vestibulaire et de son association avec l'aqueduc du vestibule.

REFERENCES

- AGAZZI C. COVA P. L. SERALINI M. *Semiotica stratigrafica dell'osso temporale* (I Italian). Relazione al XVI raduno del gruppo Alta Italia della Soc. Ital. Otorinolaringologica, Milano 1958.
- ANNOY H. J. The endolymphatic and perilymphatic aqueducts of the human ear. *Acta Otolaryng.* (Stockh.) 59 (1963) 140.
- DONALDSON J. A. WARFEN R. L. and WACHS B. S. Anatomical considerations II. *Laryngo scope* 75 (1963) 1497.

- — — and WRIGHT T R The vestibula and cochlear aqueducts: their variational anatomy in the adult human ear *Laryngoscope* 75 (1965) 1203
- HAUPTER D G and WRIGHT T R The vestibular system: anatomic considerations *Acta oto laryng* (Stockh.) 85 (1967) 53
- WARPPIER R L, DONALDSON J A and REBERG M J The gross and microscopic anatomy of the labyrinth *Ann Otol* 77 (1968) 583
- — — The developmental and adult anatomy of the membranous and ossicular labyrinths and of the otic capsule *In: Meniere's disease* p 273 Edited by J Pulec *Otolaryng Clinics of North America* 1968
- BART T H and AVERY B J The temporal bone and the ear Charles C. Thomas Springfield Ill 1949
- BECH N and BARRON-LIVIO O E Tomographie du canal endolymphatique. Intérêt dans ses obstructions *Rev Laryng* 93 (1972) 489
- BRUNGER S og BRANTS PEDERSEN C Radiologisk vurdering af aqueductus vestibuli (In Danish) *Nord Med* 86 (1971) 1029
- — Experimental roentgen evaluation of the vestibular aqueduct *Acta radiol Diagnost* 11 (1971) 443
- CLARK J and VALIASORI G E Recent radiographic and clinical observations on the vestibular aqueduct *In: Meniere's disease* p 339 Edited by J Pulec *Otolaryng Clinics of North America* 1968
- ENOSLM P The tomogram: its formation and content *Acta radiol* (1960) Suppl No 193
- JENSEN J Malformation of the middle and inner ear: Technical and practical aspects *Ann Radiol* 15 (1972) 245
- JORTER M and FERRISOLD H Étude radiomatologique de l'os temporale Masson et Cie Paris 1935
- KELLNER G and RICHTER O B Über die Entwicklung der Gefässe des Innenohres beim Menschen *Nachr Ohrenheilk* 96 (1962) 187
- LEWENSTAM P C Endolymphatic duct and sac in the guinea pig: An electron microscopic and experimental investigation *Acta oto laryng* (Stockh.) (1963) Suppl No 21 p 7
- OGURA Y and CLARK J D A study of the gross anatomy of the human vestibular aqueduct *Ann Otol* 80 (1971) 815
- PERKALOFF E Topographische Anatomie. Viertes Band 2. Hälfte S 589 Urban & Schwarzenberg München Berlin Wien 1960
- ROWEN J W Topographische Anatomie Schattauer Verlag Stuttgart New York 1971
- ROHLER R Physiologische Probleme der Betrachtung des Röntgenbildes *Röntgen Bl* 20 (1967) 79
- SCHÖNEMANN A A Schläfenbein und Schädelbasis: eine anatomisch otologische Studie *Neue Denkschriften allgem Schweiz Gesellschaft Naturwissenschaft* 40 (1906) 95
- SEK A S E, SEVTLIA B H, TAVERAS J M and REYES E T Correlation of histologic and photomicrographic sections of the temporal bone *Ann Otol* 80 (1971) 155
- SOMMER J Atlas der deskriptiven Anatomie des Menschen 3 Teil Urban & Schwarzenberg München Berlin 1957
- STRIJK F E Über den Bildaufbau in der Tomographie bei ein- und mehrdimensionaler Verteilung *Fortschr Röntgenstr* 116 (1972) 233
- WILMUND H F Tomografi av canaliculus vestibuli (In Swedish) *Nord Med* 85 (1971) 631
- WOLFE D, BELLOC R J and ERNSTON A A Microscopic anatomy of the temporal bone Williams & Williams Baltimore 197

LUMBAR MYELOGRAPHY AND ADHESIVE ARACHNOIDITIS

L IRSTAM R SUNDSTROM and B SIGSTEDT

Several reports of adhesive arachnoiditis as late sequelae after lumbar myelography with water soluble contrast media have appeared in recent years (AHLGREN 1972 1973 ADJIO et coll 1972 BJÖRSTRUP 1972 HALABURT & LESTER 1973 IRSTAM & ROSENCRANTZ 1973 1974 RADBARO & WENNBERG 1973). IRSTAM & ROSENCRANTZ have shown the occurrence of arachnoiditis to be correlated with the local concentration of contrast medium as well as with the exposure time of leptomeningeal structures to the medium. They also found an increased frequency of arachnoiditis following surgery after myelography.

However the frequency of arachnoiditis varies from one published material to another. It is not clear to which extent this variation is due to differences in technique or to the contrast media used. This investigation was undertaken to elucidate the importance of these factors.

Materials and Methods Out of 694 patients primarily examined with methyl glucamine rothalamate (Conray 60) 19 had been examined a second time.

Submitted for publication 5 February 1974

Table 1
Frequency of adhesive arachnoiditis

Contrast medium at first examination	Patients not operated upon after first examination			Patients operated upon after first examination		
	Total	With adhesive arachnoiditis		Total	With adhesive arachnoiditis	
Kontrast U	16	8	42	10	6	60
Conray 60	9	1	11	10	1	10

Table 2
Changes of radical root pockets

Contrast medium at first examination	Patients not operated upon after first examination with adhesive arachnoiditis			Patients operated upon after first examination with adhesive arachnoiditis		
	Total	With adhesive arachnoiditis		Total	With adhesive arachnoiditis	
Kontrast U	7	37		6	60	
Conray 60	1	10		(1)	(10)	

Nine of these patients (Group A) had not been operated upon before the second myelography while the remaining 10 (Group B) had been operated upon between the first and the second examination. Of 800 patients primarily examined with methiodal (Kontrast U) 19 (Group C) were not operated upon and 10 (Group D) operated upon between the first and the second examination.

The examination technique in the different series was that described by *IRSTAM & ROSENCRANTZ* (1973) but with minor differences. Myelography with Conray 60: 4 ml of medium were mixed with an equal volume of CSF and as a rule the entire dose was injected through a Stenstrom needle with an outer diameter of 1.00 mm. The head end of the examination couch was raised 10 to 15° and adjusted so that the contrast medium never reached higher than the upper border of the second lumbar vertebra. This was checked by frequent exposures during injection: no fluoroscopy was used. Films were obtained with the beam horizontal and with the patient lying first on one side and then on the other, always starting on the symptomatic side. true lateral views were taken with the patient prone. Finally p.a. views were obtained with the patient prone and the beam vertical.

Table 3

Changes in root pockets. Patients examined first with Kontrast U not operated upon (Group C)

Severity	Root pockets with changes			
	S 3	S 2	S 1	L 5
Grade 1	1	1	4	0
Grade 2	1	2	0	0
Grade 3	3	3	1	0
Grade 4	1	0	0	0
Grade 5	1	0	0	0

Table 4

Changes in root pockets. Patients examined first with Kontrast U operated upon (Group D)

Severity	Root pockets with changes			
	S 3	S 2	S 1	L 5
Grade 1	2	2	0	1
Grade 2	0	0	0	0
Grade 3	4	1	1	0
Grade 4	0	0	0	0
Grade 5	0	0	0	0

Myelography with Kontrast U 10 ml of contrast medium after spinal anesthesia by 1 ml of heavy lidocaine (Xylocain) were injected through the same type of needle as in the Conray series. The patients were examined only lying on the symptomatic side, then in prone position with the beam horizontal finally post views with vertical beam and with the patient prone.

After the examination the Kontrast U patients rested supine with the head end of the bed slightly raised for 4 hours and thereafter in horizontal position for approximately 20 hours. The patients examined with Conray 60 rested for 10 hours with the head end elevated 45° and then for approximately 12 hours with the bed horizontal.

The films and records of all patients were evaluated jointly by the authors. Adhesive arachnoiditis was considered present when (1) the ends of one or more root pockets were rounded and corresponding nerves within such pockets were less well defined or (2) when a root pocket was not filled at all and the visibility of the corresponding nerve was impaired within the cul de sac near the oblitera-

Table 5

Changes in the cul-de-sac

Contrast medium at first examination	Patients not operated upon after first examination with adhesive arachnoiditis		Patients operated upon after first examination with adhesive arachnoiditis	
Contrast U	6	32	4	40
Courtesy 50	0	0	0	0

Table 6

Changes in root pocket cysts

Contrast medium at first examination	Patients not operated upon after first examination with adhesive arachnoiditis		Patients operated upon after first examination with adhesive arachnoiditis	
Contrast U	2/	40	0/1	0
Courtesy 50	0/3	0	(1)/5	(20)

ted pocket, (3) when the cul de sac was constructed within an area with such root pocket changes and (4) when root pocket cysts were less well filled or not at all at repeat myelography.

A local deformation of the subarachnoid space at the site of a previous operation for disc herniation was not interpreted as adhesive arachnoiditis.

The changes due to adhesive arachnoiditis were graded as follows:

(A) Impaired filling of root pockets: Grade 1 Incomplete filling on one side normal on the other; Grade 2 Incomplete filling on both sides; Grade 3 No filling on one side normal on the other; Grade 4 No filling on one side incomplete on the other; Grade 5 No filling on either side.

(B) Abnormalities in the appearance of the cul de sac: its caudal extension in the spinal canal as well as of visibility of nerve roots in the caudal part of the subarachnoid space.

(C) Root pocket cysts: the extent to which they were filled and their appearance.

Results

The frequency of adhesive arachnoiditis appearing at repeat myelography is given in Tables 1 to 6.

Table 7

Frequency of adhesive arachnoiditis according to recalculated figures of AHLGREN (1972-1973) and present series pooled with them of ERSTAM & ROSENCRANTZ (1973-1974)

Contrast medium at first examination	Patients operated upon after first examination			Patients not operated upon after first examination		
	Total	With adhesive arachnoiditis		Total	With adhesive arachnoiditis	
Kontrast U/Contrast						
AHLGREN	138	60	43	50	5	10
Pooled series	60	45	75	51	18	35
Contray 60						
AHLGREN	55	29	53	16	7	47
Pooled series	19	5	23	12	1	8
Dimer X						
AHLGREN	32	25	72	11	4	36
ERSTAM & ROSENCRANTZ	12	5	42	7	0	0

Root pockets In the Contray 60 material root pocket changes were found in 1 case in Group A with grade 5 changes of the S3 pockets and 1 case in Group B with grade 3 changes of the S3 pockets.

In the Kontrast U material, changes of the S3 root pockets of Group C were found in 7 of S2 in 6 and of S1 in 5. Corresponding changes in Group D were found in the root pockets of S3 in 6 cases of S2 in 3 of S1 in 1 and of L5 in 1 (Tables 3-4).

Cul de sac The cul-de-sac was deformed only in the Kontrast U group (Table 5). The deformation was combined with root pocket changes in all cases except 1 of Group C. At re-examination of this patient the cul de sac was 7 to 8 mm shorter than before and a slight narrowing of the cul de sac 5 mm above the caudal end of the subarachnoid space had occurred. The shortening and the deformation of the cul de sac resembled what was seen in the other cases and as no other explanation could be offered it was interpreted as adhesive arachnoiditis. At further myelography typical and extensive arachnoid changes appeared which supported our assumption.

In all patients with deformation of root pockets at repeat myelography the corresponding nerves in the cul de sac were only poorly visible near the origin of the pockets. When the deformation was bilateral no nerves could be identified in that part of the subarachnoid space.

Table 8
Frequency of adhesive arachnoiditis after second myelography

Procedure judged to be subsequent myelography	No. of patients	New arachnoiditis	Accentuation of existing arachnoiditis	Unchanged adhesive arachnoiditis	No arachnoiditis	Frequency of new/accentuated arachnoiditis
LxP	8	—	3	1	4	3 43
Lxhop	6	1	4	—	1	83
LxC	3	—	—	1	2	0 0
LxCop	2	—	1	1	—	1 50
CxCop	2	—	1	—	1	1 50

L = lumbar myelography performed with contrast U

C = lumbar myelography performed with Conray 60

x = patient either operated upon or not after preceding myelography

— = no operation for disc herniation after preceding myelography

op = operation for disc herniation after preceding myelography

Root pocket cysts Root pocket cysts were demonstrated at primary myelography in 3 patients in Group A, 5 patients in Group B, 5 in Group C and 1 in Group D. The cysts appeared at two or more levels bilaterally in all cases except in 1 in Group C where they were only unilateral. In a further case of Group C only one side was evaluable at primary myelography. At repeat myelography the root pocket cysts were always less well filled in connection with changes of the corresponding root pockets. In all these cases a deformation was also found at the corresponding level in the cul de sac (Tables 5, 6).

In one case examined with Conray 60 nearly all the medium was deposited subdurally at the primary examination; no structures within the subarachnoid space were demonstrable. Repeat myelography 9 days later revealed arachnoiditis of both S3 root pockets with a decreased definition of corresponding nerves.

Five months later the patient was re-examined with Conray 60; the unpaired definition of the nerves in the lowest part of the cul de sac had extended 2 to 3 mm further cranially and was slightly more marked on that side where the contrast medium had had the highest concentration at the second myelography. Bilateral root pocket cysts demonstrated at the second examination were not filled at the third myelography. The patient's record contained a history of meningitis of unknown type 17 years earlier and rheumatoid arthritis during at least 15 years.

The changes observed at the second examination were considered to be present already at the first myelography being the only case in our series with a primary adhesive arachnoiditis. In the statistical analysis the two first examinations were regarded as one: the figures concerning this case are given in brackets in Tables 2 and 6.

One case was excluded; however it is the only case where arachnoiditis was confirmed at operation: therefore some further details will be reported.

The patient, aged 37, had signs of a disc herniation of L5-S1 at the primary myelography performed with Kontrast U. Operation revealed a bulging disc but no true disc herniation. At repeat Kontrast U myelography on the same side one month later total obliteration was found at the level of L5-S1; thus no structures could be demonstrated below this level and the case had to be excluded. Operation following the second myelography revealed a large disc herniation which was removed.

At a third myelography performed a further 10 months later and with the same technique and on the same side a slight postoperative local deformation at the level of L5-S1 was found, also two small defects appearing as strands in the contrast medium were observed in the most caudal part of the cul de sac: these defects might be explained as small strands of connective tissue due to adhesive arachnoiditis.

A further 6 months later (in all 26 months after the primary myelography) attempts to perform a fourth myelography were unsuccessful. Operation revealed a slightly reddened dura completely unelastic and without pulsations and surrounded entirely by fibrous tissue: when the dura was opened further masses of fibrous tissue were found but no CSF. Thus wide spread arachnoiditis was observed from the middle of L3 down to the middle of S1. Further surgery was considered meaningless.

Our material includes 21 cases in which more than two myelographies had been performed (Table 8). The material is small especially in view of the fact that different techniques were used and surgery was performed in between the examinations in some of the patients. Nevertheless, an analysis of the cases was considered worthwhile in order to get an idea of the extent to which previous myelography or surgery enhances the risk of arachnoiditis.

In 13 of the cases arachnoiditis was found at the third myelography. In 3 of them they had the same appearance as at the second but in 9 they had increased between the second and the third: in these cases the arachnoiditis was very extensive with involvement of the most caudal part of the cul de sac as well as of the root pockets on both sides at several levels. The thirteenth patient developed arachnoiditis after the second Kontrast U myelography.

Discussion

Repeat myelography often reveals abnormalities of root pockets and adjacent structures in the most caudal part of the subarachnoid space differing from those of an extradural process such as a disc herniation or a local post-operative

deformation. It is widely accepted that such subarachnoid changes as described above are due to adhesive arachnoiditis though only few radiologically demonstrated cases have been confirmed at operation or autopsy (IRSTAM & ROSENCRANTZ 1973, 1974). It is obvious that before the report of AUTIO *et coll.* 1972 no effort had been made to reveal the factors contributing to the development of these adhesive arachnoiditic changes.

In the present series the most severe adhesive arachnoiditis was found in the lowest part of the subarachnoid space. It decreased in cranial direction (Tables 3-4). The arachnoiditis was always more marked on the examined side in the Kontrast U material (Group C and D) or on that side, examined first in the Conray 60 material (Group A and B) when arachnoiditis appeared bilaterally. In any case of either group it was more extensive on the side examined first.

In all our Conray 60 myelographies as well as in all with Kontrast U the radiologically highest concentration of the contrast medium appeared in the most caudal part of the cul de sac. During the examination the concentration of the medium decreased uniformly, probably partly owing to absorption partly to diffusion to other parts of the subarachnoid space. This means that the arachnoiditic changes occurred where the concentration of the medium at preceding myelography had been highest and where the meninges had been exposed to the medium for the longest time.

In the Kontrast U material of IRSTAM & ROSENCRANTZ both sides were examined by the method of HIRSCH *et coll.* (1969) in the present material the patients were examined only lying on the symptomatic side and prone. As a rule only the S2 and S3 root pockets on the contralateral side were then demonstrable. Consequently root pockets and other structures above S2 level on the contralateral side could not be interpreted in most cases where repeat myelography was performed with Kontrast U. The true frequency of bilateral arachnoiditis might thus be slightly higher than the figures given in the tables. However the frequency of arachnoiditis in the present Kontrast U material was nearly equal to that in the series of IRSTAM & ROSENCRANTZ where both sides had been examined at the same myelography.

In comparison between different materials the interval between the first and the second myelography must be considered since the arachnoiditis may require some time to develop. In the present material the interval between the first and the second examination was somewhat shorter in the Conray 60 groups than in the Kontrast U groups.

The interval between the two examinations of Group A ranged from 7 days to 24 months (mean 7.7 months). In Group B the interval ranged from 2 to 34 months (mean 11 months) while the corresponding figures for Group C were 4 days to 47 months (mean 15.5 months) and of Group D 4 to 90 months.

(mean 24.5 months). The different intervals were nearly identical with those reported by IRSTAM & ROSENCRANTZ though none of their patients were re-examined within as short an interval as 4 or 7 days. In the present series the earliest case of arachnoiditis appeared 5 months after myelography with Conray 60; the corresponding interval after Kontrast U myelography was 4 months.

No positive correlation was found in any of the groups between frequency spread and severity of adhesive arachnoiditis and interval between the examinations. This was in agreement with the report of IRSTAM & ROSENCRANTZ. The caudal extension of the cul de sac did not seem to have any influence on the occurrence of arachnoiditis in any of the groups.

The pathology of a disc herniation is well known (e.g. HADLEY 1964; BROWN 1971). However, only few reports on the irritating effects of such hernias on the meninges, sometimes producing arachnoiditis of a localized type, have been published (FRENCH 1946; RANSFORD & HARRIS 1972). A diffuse and pearly white thickening of the leptomeninges with a fusion of the pia and arachnoid by fibrous and with foci of encroachment on the subdural space have been observed. The arachnoiditis may compress the spinal roots resulting in demyelination, destruction of nerve fibers and even replacement of the nerve fibers by fibrous tissue. The vascularity of the pia is decreased and in some cases the pia is completely devoid of vessels (FEDER & SMITH 1962).

Following operation for a disc herniation a local scarring, i.e. an inflammatory and local process, either intra- or extradural, may occur (FRIBERG & HULT 1950).

The pathology of small radiologically described arachnoiditis is absent. In a few cases (IRSTAM & ROSENCRANTZ) fibrous strands have been observed at opening of the dura during operation.

The radiologic appearance of a disc herniation in the lumbar region is well known as well as its correlation to pathology. Repeat myelography often reveals a local deformation at the site of a previous operation (CROQVIST 1959; IRSTAM & ROSENCRANTZ 1974). This deformation might involve the root pockets, the roots and also the cul de sac. Such deformations can be regarded as a late sequela after a local trauma during surgery (FRIBERG & HULT).

Adhesive arachnoiditis on the other hand is usually more diffusely spread and always more marked in the most caudal part of the cul de sac, irrespective of whether surgery has been performed or not. Thus these abnormalities appear radiologically different to those of a postoperative deformation. Furthermore, a local postoperative deformation might be found without co-existing adhesive arachnoiditis. In other cases an area with normal root pockets, roots and cul de sac may be observed between a local postoperative deformation and abnormalities caused by adhesive arachnoiditis.

The etiology of spinal adhesive arachnoiditis can be divided into six groups (1) agents injected into the subarachnoid space (2) infection, (3) trauma, (4) space-occupying lesions (5) intrathecal haemorrhage and (6) idiopathic (RANSFORD & HARRIES)

The local postoperative deformations have a traumatic origin possibly caused by mechanic or local vascular factors. The adhesive arachnoiditis in the most caudal part of the cul de sac, seems to be caused by the injected foreign material thus having another pathogenesis than the postoperative deformation. The high osmolality of the compounds or other toxic effects of the contrast media might play an important role in producing the arachnoiditis in the cul de sac.

Operation on the lumbar spine following myelography increases the risk of arachnoiditis (IRSTAM & ROSENCRANTZ). In the present Kontrast U material, the frequency of arachnoiditis was higher in those patients operated before repeat myelography than in those not operated upon however the difference was smaller than in the series of IRSTAM & ROSENCRANTZ. Also in the material of AHLGREN (1973) the frequency of arachnoiditis was higher among the operated re-investigated patients than in those not operated upon (Table 7). No explanation can be offered for this difference. The disc herniation as such might influence the later development of arachnoiditis but cannot by itself explain the high incidence of post operative arachnoiditis. Microvascular traumatization of the arachnoid at operation might be a contributing factor.

A short interval between myelography and surgery has been considered to increase the risk of later development of arachnoiditis. Our Kontrast U material was analyzed in this respect but produced no evidence in support of this theory.

The result of the present investigation and that of IRSTAM & ROSENCRANTZ are in many respects similar. In Table 7 the results have been compiled and compared with recent reports by AHLGREN (1972, 1973). He treated his results statistically in a way differing from that used in the two Swedish materials. Table 7 presents the extracted true two first examinations of AHLGREN's material, thus making the different materials statistically comparable. By treating his material in this way no statistical difference between the recalculated figures and those of the original material was encountered.

In the Swedish series i.e. the present report and that of IRSTAM & ROSENCRANTZ the frequency of arachnoiditis is high following Kontrast U after Conray 60 or Dimer X, the corresponding figures are low. In the Danish series of AHLGREN arachnoiditis appeared more often after Conray 60 or Dimer X than after Kontrast U.

The differences in frequency of arachnoiditis of the Swedish series and the Danish both absolute and relative between the different groups are evident. The factors responsible for these differences are not clear.

The main criteria of adhesive arachnoiditis seem to be the same in the Danish and the two Swedish series. In the Swedish materials postoperative local deformations were not interpreted as adhesive arachnoiditis for reasons mentioned, while it is not clear whether such postoperative changes were included by AHLGREN. The methodical contrast medium used in Denmark was chemically identical with that in the two Swedish series but was from a different factory in the Danish series procaine was used as spinal anaesthetic, while lidocaine was used in the Swedish. Ten to 18 ml of methodal were used in the Danish examinations and 10 to 12 ml in the Swedish.

The Conray 60 and Dimer X products used in the different series were from the same batches. Four ml Conray 60 were diluted in 4 ml of CSF the total amount was injected i.e. 1 120 mg of iodine in a concentration of 140 mg I/ml. In the series of IRSTAM & ROSENCRANTZ 5 ml of the medium were diluted in 2 to 4 ml of CSF and as a rule the whole amount was injected the corresponding total amount of iodine used was 1 400 mg in a concentration of 155 to 200 mg I/ml. AHLGREN used an individual dosage but generally 7.5 ml of Conray 60 mixed with 2.5 ml of CSF the amount of iodine was up to 2 100 mg at a concentration of 210 mg I/ml. GONSETT (1971) suggested a maximum amount of 5 ml Conray 60 (280 mg I/ml) for lumbar myelography this limit was based on acute toxicity investigations in guinea pigs and clinical experience in man. No reports in the literature dealing with possible leptomeningeal changes following myelography with different amounts of this medium have been traced.

Theoretically a possible explanation of the different frequencies of arachnoiditis in the two Swedish and the Danish materials might be that AHLGREN used a larger dose of Conray 60 and Dimer X i.e. a dose toxic enough to cause a higher frequency of arachnoiditis. However this theory cannot be applied on the Kontrast U series where a high dose of the medium in AHLGREN's series resulted in a lower frequency of arachnoiditis than in the Swedish series using a smaller dose of Kontrast U.

The positioning technique in the different methodal groups was mainly the same. However the Danish Conray 60 and Dimer X patients were examined sitting while the majority of the patients in the Swedish series were examined lying. After the examination the Danish and the Swedish patients were treated in the same way. AHLGREN like IRSTAM & ROSENCRANTZ pointed out that arachnoiditis was never observed earlier than after 30 days. Therefore AHLGREN excluded all patients with repeat myelography earlier than 30 days after the first examination. In the present material few cases were examined earlier than 30 days after primary myelography exclusion of these early cases would cause no evident change in the frequencies of arachnoiditis in the different groups.

Thus no uniform explanation can be offered for the remarkable difference

of the series of AHLGREN on one hand, of IRSTAM & ROSENCRANTZ and of the present material on the other. Possible differences of interpretation of the different materials might offer at least some explanation of the denoted differences. Other factors might be different amounts of contrast medium used and different drugs used for spinal anaesthesia.

In a short unpublished series of myelography with Kontrast U Conray 60 and Dimer V, GÖRQVIST (1972-1973) found the frequencies of arachnoiditis to be similar to those in the two other Swedish materials.

HALABURT & LESTER (1973) proposed a connection between high protein content of CSF and later arachnoiditis. AHLGREN (1973) found no such correlation. In the present series no analyses were performed of the CSF; however in the series of IRSTAM & ROSENCRANTZ protein analyses were performed in most cases. The protein content was correlated with later occurring arachnoiditis but no correlation was found.

SUMMARY

Adhesive arachnoiditis was much more common after myelography with Kontrast U than after myelography with Conray 60. Surgery following Kontrast U myelography raised the incidence of later adhesive arachnoiditis; this was not observed following Conray 60. The results indicate that patients already having adhesive arachnoiditis should not be further examined with lumbar myelography except for exclusion and cautions and then never with Kontrast U.

ZUSAMMENFASSUNG

Fine adhesive Arachnoiditis war wesentlich häufiger nach Myelographie mit Kontrast U als nach Myelographie mit Conray 60. Chirurgie nach einer Kontrast U Myelographie erhöhte das Vorkommen einer späteren adhesive Arachnoiditis; eine solche wurde nicht nach Conray 60 beobachtet. Die Ergebnisse deuten darauf hin, dass Patienten die bereits eine adhesive Arachnoiditis haben nicht durch lumbale Myelographie untersucht werden sollten mit Ausnahme besonderer Indikationen und dann niemals mit Kontrast U.

RÉSUMÉ

L'arachnoïdite adhésive est beaucoup plus fréquente après myélographie avec le Kontrast U qu'après myélographie avec le Conray 60. L'intervention chirurgicale après myélographie à Kontrast U augmente la fréquence d'une arachnoïdite adhésive tardive. Ceci n'est pas observé après Conray 60. Ces résultats montrent que les patients qui ont déjà une arachnoïdite adhésive ne devraient pas être examinés par myélographie lombaire sauf pour des indications impératives et dans ce cas jamais avec le Kontrast U.

REFERENCES

- ANDERSEN P.: Postmyelografiske eller postoperative arachnoiditiske forandringer efter Conturex-Contray- og Dimer-N-myelografier (In Danish). Paper read at the Danish Radiological Soc. Meeting, Copenhagen, October 1972.
- Long term side effects after myelography with water soluble contrast media — Conturex-Contray Meglumine 282 and Dimer-N. *Neuroradiology* 11 (1973) 206.
- AUTIO E., SUOLANEN J., NORRBACK S. and SLÄTTI I.: Adhesion arachnoiditis after lumbar myelography with meglumine oithalamate (Contray). *Acta radiol. Diagnosis* 12 (1972) 17.
- BIDSTRUP P.: A case of chronic adhesive arachnoiditis after lumbar myelography with methiodal sodium. *Neuroradiology* 3 (1972) 157.
- BROWN M. D.: The pathophysiology of disc disease. *Orthop. Clin. N. Amer.* 2 (1971) 339.
- CAROMQVIST S.: The postoperative myelogram. *Acta radiol.* 32 (1959) 45.
- Personal communications 1972-1973.
- FAIRBANK J. H. and SUTHER J. L.: Roentgen therapy in chronic spinal arachnoiditis. *Radiology* 78 (1962) 192.
- FRENCIS J. D.: Clinical manifestations of lumbar spinal arachnoiditis. *Surgery* 20 (1946) 718.
- ILMARINEN S. and HULT L.: Comparative study of broad myelogram and operative findings in low back pain and sciatica. *Acta orthop. scand.* 20 (1950) 303.
- GOMETTE R.: An experimental and clinical assessment of water soluble contrast media in neuroradiology. A new medium—Dimer-N. *Clin. Radiol.* 22 (1971) 44.
- HADLEY L. A.: Anatomical roentgenographic studies of the spine. Charles C. Thomas Publishers, Springfield, Ill. 1964.
- HALLARIET H. and LESTER J.: Leptomeningeal changes following lumbar myelography with water soluble contrast media (Meglumine oithalamate and methiodal sodium). *Neuroradiology* 5 (1973) 70.
- HENICH C., ROSENCRANTZ M. and WICKBOM I.: Lumbar myelography with water soluble contrast media with special reference to the appearances of root pockets. *Acta radiol. Diagnosis* 8 (1969) 34.
- IRSTAM L. and ROSENCRANTZ M.: Water soluble contrast media and adhesive arachnoiditis. I. Reinvestigation of non-operated cases. *Acta radiol. Diagnosis* 14 (1973) 497.
- Water soluble contrast media and adhesive arachnoiditis. II. Reinvestigation of operated cases. *Acta radiol. Diagnosis* 15 (1974) 1.
- RÄDBERG C. and WENNERBERG L.: Late sequelae following lumbar myelography with water soluble contrast media. *Acta radiol. Diagnosis* 14 (1973) 507.
- RANDFORD A. O. and HARRIS B. J.: Localized arachnoiditis complicating lumbar disc lesions. *J. Bone Jt. Surg.* 54B (1972) 656.

✓ ORBITAL PHLEBOGRAPHY

I Technique

JAN BRISMAR

Conventional skull examination and carotid angiography are generally the only roentgenologic procedures used to demonstrate lesions of the orbit. In most cases, however, these two methods are insufficient and complementary diagnostic procedures are needed. Orbitography with positive or negative contrast medium may give valuable diagnostic information (LOMBARDI 1957, BELISVER 1969, BERTELSEN 1962) but they are not easy to handle (LOMBARDI 1972) and the results may be difficult to interpret. Furthermore serious complications have been described from orbitography with positive medium (HANSEN 1956, LOMBARDI 1972) as well as with gas (GARCIN & DAVIS 1966, LOMBARDI 1967).

In addition, none of the methods will directly demonstrate the intraorbital veins. Some of the important intraorbital disorders are primarily venous i.e. malformations (ARON ROSA et coll 1966, LLOYD et coll 1971) or venous thrombosis (ARON ROSA et coll 1966, HAYE et coll 1970) and are therefore best demonstrated by phlebography.

The superior ophthalmic vein has a more constant course than the intraorbital arteries (VIGNAUD et coll 1972). A possible displacement caused by a

Submitted for publication 21 December 1973

localized intraorbital mass should thus be easier to disclose by phlebography than by carotid angiography.

Orbital phlebography thus appears to be the method of choice for evaluation of intraorbital disorders. It was, in fact, introduced as early as 1951 by DEJEAN & BOUDER and its diagnostic value has been stressed by HANAFEE (1972) and LOUBARDI (1972) among others. However, orbital phlebography appears not to be generally employed.

The purpose of the present investigation has been to develop orbital phlebography into a simple and reliable routine method that may be used in any radiologic department and not requiring any special equipment.

Review of the literature

By injecting contrast medium through a cannula in the surgically exposed angular vein, DEJEAN & BOUDER (1951) obtained a filling of the ipsilateral superior ophthalmic vein and thereby demonstrated intraorbital varicose veins in a patient with unilateral exophthalmus. During the following few years single pathologic cases were presented (DEJEAN *et coll.* 1953 a, b; BÉTOULIÈRES *et coll.* 1953) and in a monograph (1953) BOUDER summarized their experiences. The method was soon adopted by FISCHGOLD *et coll.* (1953) who also demonstrated that the cavernous sinus could be examined by the same technique (BREGAT *et coll.* 1952). In a monograph on unilateral exophthalmus, YAŞAROLU (1957) reported that the angular vein could be percutaneously punctured. He also mentioned that if this puncture failed, a frontal vein could be used instead. Relatively extensive clinical materials using the angular approach were reported by ARSENT *et coll.* (1965) and by AROY ROSA *et coll.* (1966).

Since orbital phlebography via the angular vein in most cases includes a surgical procedure with ligation of the angular vein at the end of the examination, the procedure never gained widespread use and alternative methods not requiring the presence of an ophthalmologic surgeon were developed.

A method of catheterization of the anterior facial vein was introduced by BROVARYA (1964) and was employed in a material of 50 patients with possible intraorbital tumors. A method primarily intended for demonstration of the glomus jugulare retrograde jugulography was presented by GEJROT & LINDBOM (1960) but an uneven and scanty filling of the cavernous sinuses was also obtained. This technique was modified by HANAFEE *et coll.* (1965) to include bilateral catheterization of the inferior petrosal sinuses. This modification gave a more constant filling of the cavernous sinuses and also of the intraorbital veins (RAND & HANAFEE 1967; SHU *et coll.* 1968). The latter authors reported one complication. One patient developed a partial lateral medullary syndrome.

Number of patients
— 20
— 10

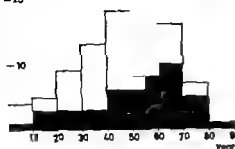


Fig. 1 Age and sex distribution of the series
□ males ■ females

presumably due to rupture of one of the pontine veins and in two patients contrast medium extravasated from the inferior petrosal sinus to the extradural space. TAKAHASHI & TANAKA (1971) demonstrated that the inferior petrosal sinuses could be catheterized via the femoral vein.

Orbital phlebography may be performed after injection into the frontal veins (YAJARGIL 1957). This method was later used by VERTSOS (1961) who advocated this approach as the method of choice. NEUBAUER & SUSSE (1966) normally using the angular vein puncture, mentioned that they on one occasion in a nervous patient successfully tried frontal vein puncture. In a later article SUSSE & KUMRSCH (1966) described a technique of percutaneous puncture of the frontal vein and demonstrated that the flow of the contrast medium may be directed by applying digital compression of the superficial facial veins. A major advantage with the frontal approach is that the veins of both orbits are simultaneously filled.

Most authors have used a scalp vein needle for the puncture but VIGNAUD & CLAY (1969) used a percutaneous teflon cannula and PISCOL (1970) advocated the use of percutaneous catheterization of a frontal vein. The angular approach however has still been preferred by some authors (SCHÖBER & BREWER 1968; McNULTY 1969).

Material

The material consists of 101 orbital phlebographies in 94 patients examined via the frontal approach up to September 1973. About 90 have been performed by the author and all except 10 since January 1972. All patients had symptoms or signs possibly related to either one or both orbits: the cavernous sinuses or the basal sinuses of the skull. The age and sex distribution of the material appear in Fig. 1. The youngest patient was a girl one day old, born with unilateral ex-



E

Fig 2 a) Position of patient for puncture with hanging head and tourniquet for venous stasis b) Patient is compressing the anterior facial veins. Position of the tourniquet has been changed towards the periphery c) Patient compressing also the supraorbital veins

ophthalmus the oldest was an 81 year-old woman with possible intraorbital tumor. Two patients below the age of one year have been examined.

Technique

Usually no preparation of the patient is needed. Several examinations were performed on an out patient basis. In a few cases 5 to 10 mg Diazepam (Valium Roche) was given intravenously or orally before the examination. General anaesthesia was used in children.

Puncturing technique The patient is placed supine on the same examination table as for cerebral angiography with the head on the automatic film changer. The couch is elevated so that the neck is extended and the head is somewhat lower than the rest of the body (Fig 2 a). The hair of the patient is covered by a sterile cloth fixed by surgical tape to the forehead and a tourniquet is placed around the head just above the supraorbital ridge, to produce venous stasis. In the first few cases of this series, a scalp vein needle was used for the puncture. Often however the examination was unsuccessful, either because of failure to puncture the vein or because of perivascular leakage during the injection. In a previous investigation (BRISMAR & GOTHLYN 1972) phlebographies of the foot were performed via standard disposable teflon cannulas with a metal mandrin for percutaneous puncture (Viggo Venflon 140). These cannulas were also used for the remaining orbital phlebographies.

After a thorough cleansing of the skin of the forehead a frontal vein is localized. This is facilitated by a spotlight directed almost tangential to the forehead.



Fig 3 Ap. ven. before application of compression to demonstrate the anatomy of the facial veins and plan the digital compression. Cannula in frontal vein (\rightarrow) Supraorbital vein (\leftrightarrow) Anacula and anterior facial vein (\leftrightarrow) Superior ophthalmic vein ($\circ \rightarrow$)

In some cases a vein can be palpated although it may not be seen. The vein is punctured as high up in the forehead as possible. The mandrin is then withdrawn and the cannula further advanced until the tip is about one cm above the eyebrows.

If no vein can be localized a blind puncture should be tried as high up in the forehead as possible about one cm lateral to the midline. The cannula is then advanced—without waiting for blood to appear in it—down towards the root of the nose and the mandrin withdrawn. The cannula is then slowly withdrawn and when blood appears advanced into the vein to a safe intraluminal position. If no blood flow is obtained the cannula and mandrin, after careful inspection of the cannula to disclose any damage to its tip are remounted and a new puncture tried. In most cases even a blind puncture is successful using this technique. When the cannula is safely positioned in the vein the tourniquet is removed.

Exposure technique A serial cut film changer was used in all cases. One film was exposed before injection of the contrast medium for subtraction. Immediately after this the injection was started and 1 to 1.5 seconds after the first film four films were exposed at 1 second intervals. The same series was used for all projections.



Fig. 4 a) Tourniquet in the ordinary position. Collaterals normally passing over the mid line to the root of the nose are in this case occluded. b) After removal of the tourniquet contrast medium passes to the left orbit as a frontal vein previously occluded by the tourniquet (\rightarrow).

The contrast medium (Iopaque cerebral Nyegaard) was manually injected using a connecting tube between the syringe and the venous cannula to decrease the radiation dose to the examiner. In some cases for examination of the cavernous sinuses, 20 ml of contrast medium were used for the axial view, other wise for all projections 10 ml were injected in about one second.

In most patients, 5 to 6 different projections were used.

(1) A p projection without compression, the beam angulated slightly from below. Most of the face was included in the view (Fig. 3). This series was reviewed before the examination was continued to judge the catheter position and the arrangement of the veins of the forehead.

To obtain bilateral filling of the intraorbital veins and the cavernous sinus the facial veins had to be compressed in order to direct the flow of the contrast medium into the orbits. Information concerning the venous anatomy of the forehead obtained from series (1) proved valuable when deciding how the compression should be applied.



b

Fig 5 a) Digital compression is applied too high on the right side and obstructs the flow of contrast medium to the right orbit. b) The digital compression now correctly applied with bilateral filling of the intra-orbital veins.

The tourniquet was reapplied this time above the catheter tip to occlude the veins of the forehead. In a few cases it was necessary to avoid compression of these veins to allow passage of contrast medium over the midline to the contralateral orbit (Fig 4). In addition the patient was instructed to apply digital compression on the anterior facial veins by firmly pressing his index fingers to the infra-orbital ridge close to his nose (Fig 2 b). It is important to avoid applying the compression too high up as this may interfere with the filling of the intra-orbital veins (Fig 5). In some cases also the supra-orbital veins had to be compressed. This was achieved by having the patient press his index fingers towards the lateral part of his eyebrows while his third fingers compressed the anterior facial veins (Fig 2 c).

During this compression the following series were exposed

- (2) A p view angulated 10 degrees from below (Fig 6 a)
- (3) Semi axial view angulated 40 degrees from below (Fig 6 c) with the teeth projected slightly below the cavernous sinus
- (4) Axial view (Fig 6 e)
- (5) Straight lateral view (Fig 6 b)
- (6) Oblique lateral view with one orbit projected above (not in front of) the other (Fig 6 d) This view allowed separation of the veins of the two orbits and as important in many cases, separated the orbital veins from the lateral parts of the supraorbital veins

Subtraction films were reviewed before the examination was considered completed. If these films were not satisfactory injection of contrast medium and serial exposure were repeated.

Results

Unsuccessful puncture attempts have during this series decreased from a fairly high percentage down to a few per cent (one failure in the last 40 patients)

The intraorbital veins were sometimes much better filled in one orbit than in the other. In order to establish the frequency of unilaterally unsatisfactory examinations the results have been classified for each orbit separately into one of the following categories

I Superior ophthalmic vein only incompletely demonstrated

II Superior ophthalmic vein demonstrated in its entire course to the cavernous sinus but only few other veins

III Superior ophthalmic vein demonstrated to the cavernous sinus, and several other intraorbital veins

A bilaterally satisfactory examination of the intraorbital veins (group III) almost always implies a diagnostic demonstration of the cavernous sinuses and adjacent basal sinuses

During the first part of this series the examinations were not infrequently classified as unsatisfactory or merely acceptable (groups I and II) while during the latter part almost all examinations have been classified as belonging to group III (Fig 7). The most important reasons for this improvement are the substitution of the teflon cannula for the scalp vein needle, and the fact that more care has been given successively to the digital compression

Complications During injection of contrast medium the patient has a sensation of tension in the forehead or intraorbitally. This sensation disappeared in a few seconds and was seldom really painful. After repeat puncture attempts a



b



d

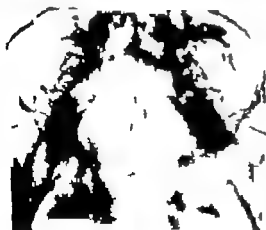


Fig 6 Projections: a) Ap view
b) Lateral view c) Semi axial view d)
Oblique lateral view with one orb
projected above (not in front of) the other
e) Axial view

~20 examinations

-10

Fig 7 Examinations performed during 1971 to 1973. The number of satisfactory examinations initially low but rises markedly towards the latter part of the series.

□ one patient in orbita
 ▨ satisfactory examination
 ▩ acceptable examination
 ■ unsatisfactory examination

1971 1972 1973

hematoma sometimes developed in the forehead. In other cases due to rupture of small veins in the forehead the medium was injected partly perivascularly. Some patients mentioned difficulties in breathing through the nose during a short period of time after each injection of the medium probably due to a transient swelling of the nasal mucosa. In fact, an accumulation of medium in the nasal mucosa is frequently observed. No other side effects or complications have been encountered in this series.

Discussion

In a review of orbital phlebography Piscot et coll (1970) estimated the total number of pathologic findings in the literature to be approximately 260 cases. The introduction of the transcutaneous frontal vein approach has made orbital phlebography much simpler since no surgical assistance is needed and the examination can be performed on out patients. As a consequence, the number of reports on orbital phlebography has increased considerably during the last few years (e.g. Lombardi & Passerini 1968, 1969; Tanaka & Suzuki 1969; Lloyd 1970, 1972; Cristobal & Del Rio Cabana 1972; Russell & Miller 1972). Even authors who earlier advocated other techniques, now prefer the frontal approach (Hanafey et coll 1968; Aron Rosa et coll 1970).

Though much simpler to perform after the introduction of frontal vein puncture the method has not gained widespread use essentially due to technical difficulties still existing (e.g. Beisner 1969; Castren et coll 1971). Hanafey et coll (1968) reported only 50 per cent success in attempting the frontal vein puncture while Lombardi & Passerini (1968) were successful in 88 per cent of their cases.

HANAFEE (1972) stresses the importance of not jumping into the conclusion of superior ophthalmic vein obstruction as lack of filling of the posterior aspects of the superior ophthalmic vein may be a purely technical result or may be related to an increased flow phenomenon. If however the compression of the facial veins has been effective the injection rapid and well developed veins connect the injection site with the orbits, there should normally be a complete filling of the superior ophthalmic vein all the way back to the cavernous sinus. In previous reports compression devices have been presented developed to facilitate the venous puncture by compressing the jugular veins (TENNER & TROSEL 1970; LEE & LIN 1971) or to direct the injected contrast medium to the intraorbital veins (HAYE *et coll.* 1970). No compression device except for the tourniquet has been used in the present series. The tourniquet in combination with digital compression applied by the patient and a rapid injection of contrast medium has proved effective enough to produce countercurrent filling of the intraorbital veins also in two cases with fistula between the carotid artery and the cavernous sinus.

Other techniques than the one described in this report (angular vein puncture, inferior petrosal sinus catheterization and even frontal vein puncture with a scalp vein needle) in most cases give results that at best can be classified as acceptable (Group II). Such a result may allow diagnosis of disorders affecting the superior ophthalmic vein though even in such cases valuable information may be lost as the small intraorbital veins are only incompletely filled. Changes of the small veins may in some cases be decisive for a correct diagnosis.

Five films were exposed in each projection. However only in a few cases did the last two films offer any additional information. Thus it seems possible to reduce the dose of radiation by exposing only three films in each projection: one film before injection of the contrast medium and after a pause of 1 to 1.5 s two films at an interval of 1 s. The first series performed without compression is used to control the position of the cannula and to give a survey of the veins of the forehead and may be replaced by a single film exposed at the end of the injection of the medium. The total number of films for the six projections is thus reduced from 30 to 16. Even without an automatic film changer and without subtraction valuable information concerning intraorbital pathology may be obtained.

As no complications have been reported using the frontal vein approach and as the examination can be performed on an out-patient basis it is suggested that orbital phlebography should be the first radiologic procedure after conventional skull examination in the investigation of intraorbital disorders. The results gained with the present method will be presented in forthcoming reports.

SUMMARY

Different techniques for orbital phlebography are reviewed and the author's method is described in detail. Experiences with this method in material of 101 orbital phlebographies are presented.

ZUSAMMENFASSUNG

Die verschiedenen Methoden für die orbitale Phlebographie werden durchgegangen und die Methode des Verfassers im einzelnen beschrieben. Erfahrungen mit dieser Methode an einem Material von 101 orbitalen Phlebographien werden dargestellt.

RÉSUMÉ

L'auteur passe en revue différentes techniques d'ophlébographie orbitaire et décrit en détail sa méthode personnelle. Il présente les résultats de cette méthode sur une série de 101 phlébographies orbitaires.

REFERENCES

1. ARON ROSA D, MORAN P, VARGAS J J et METZGER J. Exophtalmoses oedémateuses endocriniennes et blocage circulatoire sinusal orbitaire. I. Interet des phlébographies. *Ann Oculist* 203 (1970) 1.
2. RANDEZ A et METZGER J. La phlébographie orbitaire. In: L'exploration neuroradiologique en ophtalmologie, p. 136. Edité par P. Guilloit, H. Sarrau et R. Sedan. Masson et Cie, Paris, 1966.
3. ARSINI C, MIHAILESCU N, SIMIONESCU M and LAVALAN TRUEN. Orbital phlebography. *Acta neurochir* 12 (1965) 521.
4. BEESDER D H. Orbital radiography. *Surv. Ophthalmol* 13 (1969) 187.
5. BERTHELEMY T I. Pneumotomography of the orbit. *Arch. Ophthalmol* 68 (1962) 446.
6. BETOLLEBRES P, PALESTRAC R et BOLDDET CH. Premiers résultats de phlébographie orbitaire. *J. Radiol. Electrol* 34 (1953) 160.
7. BOLDDET CH. Premiers résultats de phlébographie orbitaire. Thèse Montpellier 1953.
8. BRUGAT P, DAVID M et FRASERGOOD H. Exploration du sinus caverneux par phlébographie orbitaire. *Bull. Soc. Ophthalmol. F* 33 (1952) 18.
9. BRISMAN J and GOTHLIN J. Phlebography and thrombosis of the deep veins of the foot. *Brit. J. Radiol* 45 (1972) 199.
10. BROVANA A F. Angiography in orbital lesions. (In Russian). *Vestn. Oftal* 77/2 (1964) 17.
11. CARRÉN J, VALAS A and SPJØRLOM C. Diagnosis of unilateral exophthalmos with special reference to pneumo-orbitotomography. *Acta ophthalmol. (Kbh)* 49 (1971) 273.
12. CRISTOBAL B y DEL RIO CABANA J. Nuestra experiencia en flebografía orbitaria. (In Spanish). *Radiologia (B Aires)* 14 (1972) 9.
13. DIZJA CH et BOLDDET CH. Du diagnostic des tumeurs de l'orbit et de leurs complications par la phlébographie. *Bull. Soc. franç. Ophthalmol* 64 (1951) 374.
14. VALLIERFONTE H, BOLDDET CH et PAGES F. Neurofibromatose de Recklinghausen à localisation orbitaire. *Presse méd* 61 (1953) 840.

- - GILBERT H, BOUDRY CH et PAYCHA F (b) Ptéophtalmie par anévrisme carotéide d l'orbite Presse méd 61 (1953) 840
- FITCHOLD H, BREGRET P, LE BENEHAN Y et DAVID M Iconographie de l'angiomatose neurocutanée Presse méd 61 (1953) 1790
- GARLIN R et DAVIS M Table ronde sur les indications des explorations de contraste Bull Soc franç Ophtal 79 (1966) 127
- ✓ KJØLT G and LECHEMAN A Venography of the internal jugular vein and the transverse sinuses (retrograde jugularography) Acta otolaryng (Stockh) (1960) Suppl No 158 ■ 180
- ✓ HANAUER W Orbital encephalography Radiol Clin N Amer 10 (1972) 63
- ROSEN L M, WEINER W and WILSON G H Venography of the cavernous sinus orbital vein and basal cisterns pleura Radiology 84 (1963) 751
- SHU P and DAYTON G Orbital encephalography Amer J Roentgenol 104 (1968) 29
- HANSEN E Amnionose nach Kontrastmittelfüllung der Kieferhöhle Hals Nas Ohrenarzt 6 (1956) 17
- HAYE C, CLAY C et VERNAUD J L'exploration radiologique de l'orbite Arch Ophtal (Paris) 30 (1970) 179
- ✓ LEE H F and LEE M R An improved technique in orbital encephalography with the use of Innovar and compression devices Amer J Roentgenol 112 (1971) 539
- ✓ LLOYD G The radiological investigation of proptosis Brit J Radiol 43 (1970) 1
- ✓ The localization of lesions in the orbital apex and cavernous sinuses by frontal encephalography Brit J Radiol 43 (1972) 405
- ✓ WRIGHT J H and MORRIS G Venous malformations in the orbit Brit J Ophtal 55 (1971) 505
- ✓ LONSTON G Orbithography with water-soluble contrast media Acta radiol 47 (1957) 417
- Radiology in neuro-ophthalmology Williams and Wilkins Co Baltimore 1967
- Orbital pathology and contrast media Radiol Clin N Amer 10 (1972) 115
- and PAMERL A Venography of the orbit technique and anatomy Brit J Radiol 41 (1968) 282
- - Venography of the orbit pathology Brit J Radiol 42 (1969) 184
- ✓ MCINTYRE J G Phlebography of the orbital venous system and the cavernous sinuses Brit J Radiol 42 (1969) 113
- ✓ REIBRACK H and SCHMIDT H J Die Phlebographie der Orbita über die Vena frontalis Klin Wochschr 148 (1966) 202
- ✓ REIBRACK H Die perkutane Katheterisierung der Vena frontalis zur Darstellung der orbitalen Venen und des Sinus cavernosus Fortschr Röntgenstr 112 (1970) 56
- ✓ HANAUER W and TORMAN K Die kraniale retrograde Phlebographie Acta neurochir 22 (1970) 195
- ✓ RAND R W and HANAUER W Cavernous sinus encephalography and stereotaxic cryobiphotomy J Neurosurg 26 (1967) 381
- ✓ RUSSELL D B and MILLER J D R Orbital venography Radiology 103 (1972) 967
- ✓ SCHROEDER R and BENDER R Orbita Phlebographie Fortschr Röntgenstr 109 (1968) 345
- ✓ SMITH H, HANAUER W, WILSON G and RAND R Cavernous sinus encephalography Amer J Roentgenol 104 (1968) 57
- ✓ SCHMIDT H J and KRECHTIG G Die Phlebographie der extrakraniellen Kopfvenen über die Vena frontalis Fortschr Röntgenstr 104 (1966) 184
- ✓ TAKAHASHI M and TAKAKA M Cavernous sinus encephalography Neuroradiology 3 (1971) 1
- ✓ TAKAKA M and SUGITA J Orbital and cavernous sinus encephalography J Neurosurg 30 (1969) 200

- JENNER M S and TROUZE S L A simple device for jugular vein compression Radiology 96 (1970) 60
- VICHAUD J et CLAY C Technique d'ophlébographie orbitaire par ponction directe d'une veine du front Arch Ophthal (Paris) 29 (1969) 205
- — and AUBRY M L Orbital arteriography Radiol Clin N Amer 10 (1972) 99
- VRITROS A A new method for demonstrating ophthalmic veins facial veins and superficial venous system of the head (In Greek) Arch ophthal Heter borei hellad 12 (1961) 223
- MARGUL M G Die Röntgendiagnostik des Exophthalmus unilateralis S Karger Basel 1957

PEDUNCULATED TUMOURS OF THE OESOPHAGUS

Two cases of lipoma

B LINJEQUIST and A WISEN

Benign as compared with malignant lesions of the oesophagus are usually described as rare. To consider benign tumours of the oesophagus as in themselves uncommon is however probably inaccurate as those recorded in the literature during the last few decades far outnumber all those previously reported. The reason for this is not necessarily an increased frequency but an improvement in the diagnostic procedures i.e. the development of radiographic and endoscopic techniques.

The early literature was reviewed by MACHENZIE (1884), MIYAKI (1895), BELLON (1903) and GORBEL (1904). ADAMS & HOOVER (1945) recorded 96 benign oesophageal tumours in the literature between the years 1912 and 1945 while GERLACH & STEGMAYER (1951) found less than 200 benign lesions up to 1951. TOTTER *et al.* (1953) reviewed 163 benign tumours and cysts of the oesophagus including all those previously mentioned. MOERSCH & HARRINGTON (1944) reported a frequency of 15 benign tumours in 11 000 patients with dysphagia and JACOBSON & JACKSON (1951) an incidence of 10 innocent growths in a series of 4 000 patients with oesophageal conditions other than those caused

by foreign bodies. As many of these neoplasms fail to give rise to clinical signs the true incidence of benign tumours is presumably higher. This is illustrated in a review of 7 495 autopsies with 44 benign tumours of the oesophagus (MOERSCH & HARRINGTON). SCHAFER & KITTLE (1947) reported 11 benign tumours in 6 001 autopsies. The comparatively low incidence is evident from the figures by NESE (1957) who for a ten year period reported 10 benign and 182 malignant lesions, carcinoma of the cardia being excluded. The total number reported was estimated by PALMER (1952) to lie between 200 and 300.

No commonly accepted classification of benign neoplasms of the oesophagus exists. They include a great variety of conditions among which myomas and polyps dominate. According to STOREY (1962) the polyps constitute about one third of all the benign growths, all other varieties with the exception of the myomas being most uncommon. NORA (1964) collected only 17 lipomas and lipofibromas from the literature. The latter are however not true lipomas and should according to STOREY be classified as polyps, this also applies with myxofibromas, myofibromas, lipomyomas and probably pedunculated fibromas. True lipomas are extremely rare (TERRACOL & SWEET 1958).

Benign oesophageal tumours may also be grouped by their macroscopic features and are from this point of view customarily divided into those that arise from the mucosa or the submucosa and those originating deep to these layers. They are known as intra-oesophageal or mucosal and intramural or extramucosal tumours respectively. The mucosal tumours are frequently pedunculated and appear as an intraluminal situated mass. It is usually referred to as a polyp although lipomas, fibromas and occasionally myomas and also other rare lesions may appear in a pedunculated form. Malignant tumours such as leiomyosarcomas and especially carcinosarcomas sometimes occur with more or less of a pedicle. Malignant changes in a large originally benign tumour have also been reported. The size of a pedunculated tumour may be very large and the mass may fill the whole lumen of the oesophagus. Most take their origin from the uppermost part of the oesophagus or the adjacent regions of the hypopharynx, as many as 25 of 40 polyps have been reported as attached at the level of the cricoid cartilage (TORREN *et coll.*). Mucosal tumours can also be sessile in shape and protrude into the lumen of the oesophagus.

Large intraluminal pedunculated tumours give rise to special diagnostic problems, clinical as well as roentgenologic. GLYNN (1940) collected 16 cases of large pedunculated tumours among which were 4 lipomas. SAMBON & ZILMAN (1942) accounted for 26 large pedunculated tumours and BERNATZ *et coll.* (1958) added 11 more. TANZU (1947) reported 13 grossly (over 7 cm) pedunculated tumours that had all been examined roentgenologically, among these there were 3 possibly 4 malignant lesions but no lipoma.



Fig. 2. Case 2. Tumour appearing in the mouth.

anaemia were present. After some months the difficulty in swallowing increased and again anaemia as well as a high ESR were recorded. Further roentgen examination of the oesophagus produced the same result as previously. An operation on the cardia relieved the symptoms.

Five months later a third roentgen examination demonstrated increased widening of the oesophagus but nothing else. Endoscopy now however disclosed a smooth defect. A well defined mass occupying nearly the whole of the oesophagus was evident in the next roentgen examination. It diminished in size cranially and a long pedicle was present superiorly. The lower pole of the lesion rounded and well demarcated lay immediately above the cardia (Fig. 1). A third endoscopic examination was negative but when repeated revealed the tumour pedunculated and covered with normal mucosa; the latter confirmed by biopsy.

The tumour was removed only with difficulty by cervical oesophagotomy. It was 25 cm length and 8-10 cm in diameter at its lower end; it was attached to the upper part of the oesophagus by a thin pedicle.

Pathology. A fusiform mass furnished with a pedicle, soft and homogeneous in consistency with greyish red cut surface. It was composed of fat tissue interwoven by coarse bundles of connective tissue with some vessels. The surface was covered with normal epithelium and the mucosa was partly ulcerated. No signs of malignancy. Diagnosis: Lipoma rich in vessels and partly converted into fibrous tissue.

Case 2. Man aged 83 years who for several years had noticed a lump in his throat which he now and then could make to appear in his mouth. The lump had increased in size during the last few years and difficulty in swallowing solid food had arisen but there had been no trouble with liquids. When seen the patient had a lump protruding 10 cm from his mouth (Fig. 2). Roentgen examination disclosed a large elongated tumour in the hypopharynx and the oesophagus partly deforming the left paratracheal sinus (Fig. 3). The pedicle was excised and measured 4 to 5 cm in diameter and 85 cm in length removed.

Pathology. A lobulated lipoma, banana-shaped and with a pedicle apparently benign. Microscopy revealed highly differentiated fat tissue covered with normal mucosa.

The patient died in his sleep two days after the operation. Autopsy disclosed a further polypoid mass the size of a hen's egg and furnished with a pedicle attached to the region of the right aryepiglottic fold.



Fig. 3 Case 2 Large elongated tumour in the oesophagus arising from the left perium

Discussion

The features of the two cases include most of those important in pedunculated tumours of the oesophagus. A total of 160 such tumours have been reported.

The age distribution may be compared with that of 81 leiomyomas published by STOREY. About 75 per cent of these appeared before the age of 50 and 96 per cent before the age of 60 years compared with 45.5 and 66.4 per cent respectively of 132 pedunculated mucosal tumours previously reported. An explanation of the difference may be that it takes longer for a pedunculated tumour to give rise to symptoms that take a patient to a doctor. Many of the tumours also reached a fair size before the final diagnosis was made.

Eighty-two of the 115 benign tumours occurred in men (71.3 per cent) and 33 in women (28.5 per cent). The figures for the leiomyomas are 60 and 35 per cent respectively (STOREY). Both pedunculated tumours and leiomyomas thus occur predominantly in men and in a ratio of about 2.5 to one. This difference is not so striking as that in malignant oesophageal tumours, roughly 80 per cent of which arise in men.

Of the 160 cases previously reported and the 2 cases now added, 136 consisted of benign and 26 of malignant conditions. The number of lipomas were 23 and together with the lipofibromas and a single case of myxolipoma constitute a fair portion of the pedunculated tumours (22.2 per cent). There were 11 fibromas and 7 myomas among the 162 cases, in 73 of which polyps including myxofibromas and fibromyomas predominate. Malignant tumours occurred in 26 patients and included carcinosarcomas and sarcomas equally distributed. Two of the 26 malignant growths were carcinomas; a sarcoma sometimes arose in a previously benign lesion.

Lipomas are more frequent in men than in women, the relative frequencies being 18.4 and 7.5 per cent respectively. When the lipofibromas and the single myxolipoma are included among the lipomas the figures become 29.3 and 10.0 per cent respectively. The polyps occur in 47.5 per cent of men as well as in women, the fibromas having a reverse distribution with the figures of 5.5 per cent for men and 15.0 per cent for women. No comments upon this reversal have apparently been made.

No difference in the distribution of malignant tumours between men and women appears to exist as 17.5 per cent of the pedunculated tumours were malignant in both men and women. Eight carcinosarcomas occurred in men and only 2 in women.

It is stated in the literature that benign pedunculated oesophageal neoplasms usually arise from the upper part of the oesophagus, often at the level of the cricoid cartilage. The attachment of the pedicle was given in 116 cases.

Benign pedunculated tumours issued from the upper part of the oesophagus including the level of the cricoid cartilage in 73 cases (87.9 per cent); in only 10 did the pedicle arise in the lower third and in 3 cases in the middle part of the oesophagus. Lesions with a stalk from the lower third of the oesophagus were polyps and myomas and a single cystic condition. No lipoma or fibroma arose from this region. These findings are the reverse of those reported in malignant pedunculated tumours which predominantly were attached at the lower or middle part of the oesophagus (66.0 per cent). A malignant tumour was attached with a pedicle at the upper part of the oesophagus however in 7 cases. It may perhaps be stated that the demonstration of a pedicle attached at the uppermost part of the oesophagus strongly favours the presence of a benign intraluminal tumour.

Seventy-six of the benign tumours were over 7 cm, many of them more than 20 cm in length. 21 were under 7 cm. Among the lipomas and fibromas a length of more than 7 cm dominated, 36 being larger and only 6 under 7 cm. On the other hand one third of the polyps were under 7 cm. Some of the largest tumours were however polyps. The large variety were also the more common among the

malignant growths. The size of the tumour thus seems not to play the same part as the attachment of the pedicle in reaching a correct diagnosis.

Seventy two of the 162 cases were examined roentgenologically. The size of the tumour was over 7 cm in 45 cases, under 7 cm in 16 cases and unknown in 11 cases.

Nine cases with the roentgenologic diagnosis of achalasia were among those with growths over 7 cm. Three of these were cases of lipomas (MOERSCH & HARRINGTON BAUMANN & VON HASSELBACH and Case 2 in this report) 2 were of fibromas (HAENTSCHE 1924 1938 and FAHR 1923) 3 of polyps (McBRIDE 1951 BERNATZ et coll and JOHANSSON & SILANDER 1963) and 1 of myco-fibroma (MOERSCH & HARRINGTON). The tumour always issued with a stalk from the upper third of the oesophagus. The same diagnosis was reached by endoscopy in 3 of them 2 polyps and 1 lipoma but in 6 cases this examination was negative. A second roentgen examination in 2 cases revealed an intraluminal tumour and in a further 3 cases a mass was evident in a second endoscopic examination in one of the latter although a second roentgen examination demonstrated a dilated oesophagus with filling defects, a diagnosis of cardiospasm was made.

Endoscopy produced a diagnosis of cardiospasm in one case (SERFLING & BAUMITZ 1953). Subsequent examination disclosed an intraluminal tumour at first considered to be a fibroma but finally diagnosed as a fibromyosarcoma.

The 7 cases with the final roentgen diagnosis of achalasia had sausage shaped tumours between 13 and over 20 cm in length usually reaching the cardia or the lower part of the oesophagus. In only 3 of these cases were filling defects observed (HAENTSCHE McBRIDE and BERNATZ et coll). In 2 cases with the diagnosis of achalasia the tumour was identified at a subsequent roentgen examination the mass was very large and reached the region of the cardia. In one of these cases (BAUMANN & VON HASSELBACH) the oesophoscope could not be passed into the oesophagus as it was obstructed at the entrance by a supposedly stenotic lesion. Repeat oesophagoscopy disclosed an intraluminal mass in 3 of the other 7 cases (MOERSCH & HARRINGTON 2 cases and BERNATZ et coll). A final diagnosis of achalasia or cardiospasm was thus made in 4 of the original 9 cases. Cardioplasty was performed in 4 cases and in 3 of these no tumour was evident. In one of them gastrotomy was later carried out a mass was seen through the cardia but not removed. Only a third operation and subsequent section disclosed the presence of 3 very large polyps (McBRIDE). The other 2 cases in which cardioplasty was performed also went to section and the tumour was revealed (HAENTSCHE FAHR).

A diagnosis of achalasia cardia or cardiospasm was never made either roentgenologically or endoscopically in tumours under 7 cm.

A roentgenologic diagnosis of cardiospasm was made in 2 out of 11 cases harbouring a tumour of unknown size (BERNATZ et coll.) The report concerning these 2 cases is scanty. Oesophagoscopy disclosed a stalked tumour (polyp) in both these cases, in which a mass was said to have appeared in the mouth. The roentgenologic report was nevertheless cardiospasm. JOHANSSON & SILANDER (1963) reported probable malignancy in a case at roentgen examination but a benign polyp was identified endoscopically and subsequently removed.

Conclusion

The roentgenologic changes in benign oesophageal tumours differ from those caused by malignant lesions. The signs of benign intramural lesions have been described by several authorities (SCHATZKI & HAWES 1942; HARPER & TISCENCO 1945) and large tumours in some detail by others (TANTIA 1927; PALUGAY 1932; HAENISCH 1924, 1938). Double contrast examinations (PALUGAY 1932) and recently transversal tomography (GOCKEL 1959) have been used to define the relationship between the tumour and the oesophageal wall. The demonstration of a mass within the oesophageal lumen is possible with the conventional technique with barium sulphate as the medium. One sign is of special value. The mucosa of the tumour as well as that of the oesophageal wall are usually quite normal although the folds are flattened or have disappeared due to dilatation of the oesophagus harbouring a large intraluminal mass. The surface of the latter may be grossly irregular due to its more or less lobulated shape giving the impression that it is divided into two or more separate entities. The benign tumours are sometimes multiple although a single lobulated growth is more common. No real obstruction to the contrast medium is usually encountered even when the tumour is of huge size. The growth is seen to be surrounded by a strip of contrast medium when examined in different positions and with rotation of the patient. The lower pole is usually well demarcated.

The pedicle may be difficult to demonstrate and has been sometimes impossible even when the true nature of the lesion was known to the examiner beforehand.

Misinterpretation of the condition as being due to cardiospasm may perhaps be avoided if the possibility of a large benign tumour be borne in mind. Negative endoscopy even with a negative biopsy may fail to eliminate a large benign intra-oesophageal tumour. It is possible to pass an oesophagoscope down the oesophagus in the presence of such a growth without detecting its presence. Furthermore, biopsy may prove negative as the mucous membrane covering the tumour is usually normal.

SUMMARY

A review of the symptoms and clinical signs in 160 pedunculated tumours of the oesophagus recorded in the literature and two recent cases have indicated that such growths are mainly benign in nature and are polyps, lipomas and fibromas are rare. The possibility of excluding malignancy is discussed. Achalasia cardiae appears to be a common misinterpretation of the signs observed at roentgen and endoscopy examinations.

ZUSAMMENFASSUNG

Aus der Literatur wurden 160 Fälle von gestielten Tumoren des Oesophagus gesammelt. Nach Beobachtung von zwei eigenen Fällen wurde das Gesamtmaterial auf diagnostische Zeichen und klinische Symptome überprüft. Es kommt festgestellt werden dass es sich in allgem. um gutartige Polypen handelt, selten lagen Lipome oder Fibrome vor. Die Möglichkeit einer Malignität muss in Frage gestellt werden. In der Praxis wird oft trotz Röntgenuntersuchung und Endoskopie irrtümlich eine Cardiospasmus diagnostiziert.

RÉSUMÉ

L'analyse des symptômes et des signes cliniques dans 160 tumeurs pédiculées d'oesophage publiées dans la littérature et deux cas récents ont montré que ces tumeurs sont le plus souvent de nature bénigne et sont des polypes, les lipomes et les fibromes sont rares. L'auteur examine la possibilité d'exclure le diagnostic de malignité. L'achalase du cardia paraît être une erreur d'interprétation fréquente des signes observés. Le examen radiologique et endoscopique de ces tumeurs.

REFERENCES

- (A complete bibliography can be requested from B. Lalicquart.)
 ADAMS R. and HOOVER W. B. Benign tumors of the esophagus. *J. thorac. Surg.* 14 (1947) 279.
 BAUMANN W. und O. HASSELBACH H. Ein Beitrag zur Erkennung und Behandlung der gutartigen gestielten Tumoren des oberen Oesophagus. *Langenbecks Arch. klin. Z. Chir.* 274 (1955) 347.
 BERNER T. P. E. SMITH J. L. ELLIS F. H. and ANDERSON H. A. Benign pedunculated intraluminal tumors of the esophagus. *J. thorac. Surg.* 35 (1958) 303.
 BERNON J. Les polypes de l'oesophage et du pharynx larynxé. Thèse Lille 1903.
 FATA T. Gutartiger Tumor als Passagehindernis im Oesophagus. *Klin. Wochschr.* 2 (1923) 2347.
 GERLACH W. L. and STROMAN J. G. Benign tumors of the esophagus. *Surgery* 29 (1951) 109.
 GUY E. Large pedunculated fibroma of the esophagus. *Brit. J. Surg.* 27 (1940) 610.
 GOSSEL H. P. Zur Röntgendiagnostik benignen Oesophagustumoren. *Rad. u. Onk.* 78 (1956) 1.
 GOSSEL C. Über die Lipomatosen des Hypopharynx ihre Beziehung zu den sogenannten Oesophagus Polypen und tiefliegenden Halslipomen. *Dtsch. Z. Chir.* 75 (1904) 196.
 HARNACK F. Beitrag zur Röntgendiagnostik des Oesophagus benignen Oesophagustumoren. *Fortschr. Röntgenstr.* 32 (1924) 804.

- Polypoid Ösophagustumor Fortschr Röntgenstr 58 (1938) 253
- HARPER R. A. and TIERNCO E. Benign tumors of the oesophagus and its differential diagnosis Brit J Radiol 18 (1945) 99
- JACKSON C. and JACKSON C. Bronchoesophagology W. Saunders Co Philadelphia & London 1951
- JOHANSSON L. and SILANDER T. Benign oesophageal tumors Acta chir scand 126 (1963) 1573
- MACKENZIE M. A manual of diseases of the throat and nose J. & A. Churchill London 1884
- McBRIDE A. Benign polypoid tumor of the esophagus Cancer 4 (1951) 708
- MINIKI P. R. Zur Entwicklungsgeschichte und Klinik der Polypen und polypähnlichen Gewächse des Rachens und der Speiseröhre Dtsch Z Chir 41 (1895) 513
- MOERCH H. J. and HARRINGTON S. W. Benign tumor of the esophagus Ann Otol (St Louis) 53 (1944) 800
- NEEL G. Benign tumors and cysts of the esophagus Acta chir scand 114 (1957) 165
- NORA P. F. Lipoma of the esophagus Amer J Surg 108 (1964) 353
- PALMER E. D. The esophagus and its diseases Paul B Hoeber Inc New York 1952
- PALLOTTA J. Röntgendiagnose gestielter Speiseröhrengeschwulst Röntgenpraxis 4 (1932) 939
- Röntgendiagnose gestielter Speiseröhrengeschwulst Röntgenpraxis 4 (1932) 761
- SAMSON P. C. and ZELMAN J. Pedunculated tumors of the esophagus Arch Otolaryng 56 (1942) 1203
- SCHAFER P. W. and KITTLE C. F. Esophageal leiomyoma J Amer med Ass 133 (1947) 1202
- SCRATZEN R. and HAWES L. E. The roentgenological appearance of extramucosal tumors of the esophagus Amer J Roentgenol 48 (1942) 1
- SERFLING H. J. und BAUDITZ H. Ein Beitrag zur Diagnostik und Therapie gestielter Ösophagustumoren Zbl Chir 78 (1953) 1937
- STURDY C. F. Acquired surgical lesions of the esophagus Charles C Thomas Publ Springfield Ill 1962
- TAMM C. Beiträge zur Diagnose des Ösophagustumors Über ein röntgenologisches Bild der Polypen bzw. polypösen Geschwulst im Ösophagus Fortschr Röntgenstr 36 (1927) 1204
- TANAY N. Beitrag zur Diagnose polypöser Ösophagustumoren Wien klin Wochr 59 (1947) 851
- TERRACOL J. and SWEET R. H. Diseases of the esophagus W. B. Saunders Co Philadelphia and London 1958
- TOTTEN R. S. STOUT A. P. HUMPHREYS G. H. and MOORE R. L. Benign tumors and cysts of the esophagus J thorac Surg 25 (1953) 606

ANGIOGRAPHY IN RENAL AMYLOIDOSIS

L. EKLUND and T. LINDBOLM

No reports on the angiographic appearances in amyloidosis of the kidney seem to have appeared so far. This is perhaps surprising, since amyloidosis is not uncommon and is an etiologic entity in the nephrotic syndrome and may eventually lead to renal failure (HAMSTROMER et coll 1968, BRON 1973). Six patients with histologically confirmed amyloidosis of the kidneys have been examined and the angiographic appearances, some marked with progression of the disease, are now presented.

Material and Methods The material consisted of 6 patients, 2 males and 4 females, aged from 21 to 63 years. Two of these had primary amyloidosis, 3 had amyloidosis secondary to rheumatoid arthritis, and one patient had developed amyloidosis secondary to osteomyelitis.

All the patients were examined by transfemoral aortography and bilateral selective nephroangiography. The latter was performed with 4 to 10 ml contrast medium (Isopaque Coronar Nyegård, Norway) injected into the renal artery at a suitable rate, the programme for filming usually being 2 films for 2 s, followed by a fifth and a sixth film at 2 s intervals. Phlebography was also performed in 2 patients to exclude renal vein thrombosis.



Fig. 1



Fig. 2

Fig. 1 Case 1 Right selective angiography. The kidney is enlarged (14 cm x 7 cm). Narrow intrarenal arteries. Smooth stenoses and in some places dilatation of arteries in upper pole of kidney. Interlobular arteries not filled (Contrast medium from previous pyelography in renal pelvis).

Fig. 2 Case 2 Left selective angiography. Intrarenal arteries narrowed, tortuous towards the periphery and in some places slightly irregular. No filling of interlobular arteries.

Attention was paid to kidney size, calibre of the main renal artery, the appearances and filling of intrarenal arteries, the width of the cortex and definition of the corticomedullary junction as well as to the renal circulation time and demonstration of the renal vein.

One of the patients, a 56-year-old woman, was admitted with acute renal failure. The remaining 3 patients also had reduced renal function, the endogenous creatinine clearances being 3 to 65 ml/min. In addition, four of the 6 patients had a nephrotic syndrome. The diagnosis of amyloidosis was reached by renal biopsy in 3, by rectal biopsy in one patient and by autopsy in 2 patients. Five patients have died and one is still alive after an observation period of 2 1/2 years.



Fig 3 Case 5 a) Right selecta angiography Arteriovenous fistula secondary to renal biopsy in lower pole of kidney. Narrowing of intrarenal arteries except for artery feeding the fistula b) 17 months later Closure of arteriovenous fistula Decrease in size of kidney. The calibre of the main renal artery has diminished and the intrarenal arteries have become more narrowed and tortuous

Case reports

Case 1 Woman, aged 56 admitted with acute renal failure had had rheumatoid arthritis since the age of 23 was badly disabled and had been using wheel chair for the last two decades. During the few months before admittance she had gastrointestinal symptoms with abdominal pain and diarrhoea. She was in incipient shock with poor peripheral circulation and oliguria. Angiography. The kidneys were slightly enlarged. The main renal arteries were of normal calibre but the intrarenal arteries were irregularly narrowed. The cortical arteries were not filled and the corticomedullary junction was indistinct. The renal emptying time was prolonged. Phlebography excluded thrombosis of the renal vein (Fig 1). Two days after admittance she still had oliguria with serum creatinine 11 mg/dl and serum potassium 7.0 mEq/l. Peritoneal dialysis was instituted and continued for 11 days the dialysis fluid appeared normal. Slight improvement was followed by worsening of her condition. Laparotomy disclosed ischaemic colitis of the splenic flexure.

which was rejected. She died a few hours later. Autopsy demonstrated marked general arteriosclerosis, anoxic enterocolitis and secondary amyloidosis of the kidneys, myocardium, spleen, lungs, liver, pancreas and the intestines.

Case 2 Woman aged 59 with proteinuria for 14 months was admitted with marked peripheral oedema. The protein loss in the urine amounted to 10 to 15 g/24 hours. Biopsies of the kidney as well as of the liver revealed amyloidosis. Angiography: Normal sized kidneys with slight cortical reduction. The intrarenal arteries were narrowed and somewhat tortuous; the interlobular arteries were not filled and the corticomedullary junction was indistinct (Fig. 2). Renal function rapidly deteriorated from a chromium EDTA clearance of 65 ml/min to 35 ml/min in two months. Chlorochin phosphate and penicillamine were tried but no clinical effect was noticed and the patient died four months later.

Autopsy confirmed the diagnosis of amyloidosis; the myocardium was involved as well.

Case 3 Woman aged 50 with rheumatoid arthritis for thirty years and with clinical signs on admission of a nephrotic syndrome; the diagnosis of amyloidosis was established after biopsies from the kidney and the rectal mucosa. Angiography: The kidneys were of normal size; the intrarenal arteries somewhat narrowed; the cortical arteries not filled and the corticomedullary junction indistinct. Serum creatinine 1.5 mg % and endogenous creatinine clearance 30 ml/min. Treatment with azathioprine was started a few weeks later and still continues. She initially had proteinuria of 6 g/24 hours; the albumin/creatinine clearance quotient is now 0.03 % on a normal. Renal function during the same period of observation has slightly improved.

Case 4 Man aged 60 with arterial hypertension for twenty years and for several years lassitude and diffuse abdominal pain; the serum creatinine concentration was elevated to 2.0 mg % in 1963. An examination about that time included angiography and renal biopsy. The renal specimen suggested amyloidosis; a diagnosis that could not be definitely confirmed. Angiography: Somewhat reduced kidney size. The main renal arteries were normal but the interlobar arteries were slightly irregular; the cortical arteries were not filled and the corticomedullary junction was indistinct. During the next two years the renal function gradually decreased and in January 1966 the patient died in uraemia. Autopsy revealed contracted kidneys with amyloidosis.

Case 5 Woman aged 21 with rheumatoid arthritis for six years. Renal biopsy was performed for a nephrotic syndrome of six months' duration; this as well as biopsy of the rectal mucosa revealed amyloidosis. Angiography of the kidney was performed about seven months after this when the patient had an endogenous creatinine clearance of 13 ml/min and the serum creatinine was 4.4 mg %. Further angiography was performed 17 months later. At the first angiography a retrovenous fistula secondary to renal biopsy had been demonstrated in the lower pole of the right kidney. At the second angiography the fistula had closed; the kidneys were smaller and the main renal artery as well as the intrarenal arteries narrowed (Fig. 3). The renal function had then further decreased; the endogenous creatinine clearance being 3 ml/min and the serum creatinine 10.2 mg %. (This case is also described in a previous report by EKLUND & LINDHOLM 1971.)



Fig 4 Case 6 Contracted kidney with irregular surface a) Aortic injection Narrowing of main renal artery The interlobular arteries are somewhat dilated with focal irregularities and absence of normal tapering b) Selective angiograph Dilatation of arteries as result of selective injection of contrast medium Distance between capsular artery and renal surface indicates shrinkage of the kidney c) Nephrographic phase

Case 6 Man aged 46 with history of osteomyelitis of the right femur for 33 years had also had recurrent urinary infection for 3 years. The patient was admitted in 1970 after period of rapid deterioration with serum creatinine of 23 mg % peritoneal dialysis as instituted. Biopsy of the rectal mucosa negative in 1968 now disclosed amyloidosis. Angiography: Markedly contracted kidney (Fig 4). Intermittent peritoneal dialysis was continued but after about thirty treatments abdominal adhesions made further treatment impossible and the patient died in uraemia.

All 6 patients thus had abnormal angiographic findings. In one patient the kidneys were slightly enlarged in 2 they were normal in size and in 3 patients their size was reduced. The interlobular arteries were not demonstrated and the

corticomedullary junction was indistinct in Cases 1, 2, 3 and 4. The main renal artery was normal in calibre in these cases, but the interlobar arteries were narrowed or irregular or both. Cases 5 and 6 had narrowed main renal arteries and marked cortical reduction. The renal vein was always open in two cases proved by phlebography.

Discussion

Amyloidosis may be primary or secondary but is usually secondary to chronic conditions such as osteomyelitis, polyarthritis or tuberculosis. The disease was considered primary in 2 of the present cases and secondary in 4 of the cases. The kidney together with the liver and spleen are the organs usually involved in generalised secondary amyloidosis (BRANDT *et coll.* 1968). From the renal aspect the disease may present itself in the form of a nephrotic syndrome as in 4 of the cases. With progression of the condition, renal insufficiency and uraemia may develop as in all the cases.

Vascular lesions are characteristic with thickening of the vessel walls, the lesions affecting not only the glomerular tufts but also vessels of any size in the renal parenchyma (COHEN 1967). These vascular changes were also reflected in the angiographic findings in the present 6 cases of amyloidosis, in which narrowing, tortuosity and irregularity of the intrarenal arteries were common. Fibrosis of interstitial tissue may lead to contracted kidneys as in 3 of the cases, this usually being a late manifestation.

One interesting feature in the material was the development of an arteriovenous fistula secondary to renal biopsy. This illustrates two important features concerning such fistulas: (1) The risk of fistula formation is increased in cases with abnormalities of renal vessels and (2) the high incidence of spontaneous closure of such fistulae (EKELYND & LINDHOLM 1971, EARLYND *et coll.* 1972).

BARCLAY *et coll.* (1960) after collecting 48 cases, considered renal vein thrombosis an important and often terminal complication of renal amyloidosis. On the other hand HELLEKANT & KAUDE (1972) failed to find evidence of amyloidosis after reviewing 33 cases of renal vein thrombosis. In all the present cases the renal vein was open. This differential diagnosis has to be considered with a nephrotic syndrome however and if it is difficult to demonstrate the renal vein from the arterial side phlebography should be performed, eventually enhanced by the introduction of epinephrine into the renal artery (OLIN & REUTER 1965). The angiographic findings in renal amyloidosis may from the differential diagnostic point of view resemble those in chronic glomerulonephritis in which non-filling of the interlobular arteries and an indistinct

cortico-medullary junction are fairly common (EKLUND et coll 1972). In glomerulonephritis, however, the more proximal intrarenal arteries are usually only slightly involved. The differential diagnosis against chronic pyelonephritis may be impossible in the end stage with contracted kidneys. A clinical history of a chronic condition such as osteomyelitis or polyarthritis should however keep the diagnosis of renal amyloidosis well to the fore.

SUMMARY

The angiographic findings in 6 patients with histologically confirmed renal amyloidosis both primary and secondary are presented. All the patients had abnormal angiograms but renal vein thrombosis was not encountered.

ZUSAMMENFASSUNG

Die angiographischen Befunde bei 6 Patienten mit histologisch nachgewiesener renal Amyloidose sowohl primärer als auch sekundärer werden beschrieben. Alle diese Patienten hatten pathologische Angiogramme jedoch wurden keine Venenthrombosen gefunden.

RÉSUMÉ

Présentation des signes angiographiques constatés chez 6 malades atteints d'amyloidose rénale confirmée histologiquement primaire et secondaire. Tous ces malades avaient des angiographies anormales mais on n'a pas trouvé de thrombose des veines rénales.

REFERENCES

- BARCLAY G P T, CAMERON H, MACD. and LOU. BRIDGE L W. Amyloid disease of the kidney and renal vein thrombosis. *Quart J Med* 25 (1960) 157.
- BRANT K, CATHERART E S and COHEN A S. A clinical analysis of the course and prognosis of forty two patients with amyloidosis. *Amer J Med* 44 (1967) 935.
- BRON J. The kidney. p 390. Butterworths London 1973.
- COHEN A S. Amyloidosis. *New Engl J Med* 277 (1967) 678.
- EKLUND I. and LINDHOLM T. Arteriovenous fistulae following percutaneous renal biopsy. *Acta radiol* 11 (1971) 38.
- GOTTLIEF J, LINDHOLM T, LINDHEDT E and M. THOMAS K. Arteriovenous fistulae following renal biopsy with hypertension and hemodynamic changes. Report of four cases studied by dye-dilution technique. *J Urol* 108 (1972) 373.

- HAUDE J and LINDHOLM T Angiography in glomerular disease of the kidney. A correlation with clinical findings and the stage of the disease. *Amer J Roentgenol* 119 (1973) 739
- HAMBURGER J, RECHET G, CROSIER J, FLECK BREYTA O, J L ANTONCE II, DUCROT H, MER J P and DE MONTEA II *Nephrology* p 89 W B Saunders Co Philadelphia 1968
- HELLERAST C and HAUDE J Vercroventhrombose *Radiologe* 11 (1972) 349
- OLIN T and REITER S A pharmacoradiographic method for improving nephroplebography *Radiology* 83 (1965) 1036

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF E OLSSON)
UNIVERSITY HOSPITAL S 721 85 LUND SWEDEN AND THE DEPARTMENT OF RA-
DIOLOGY (CHAIRMAN PROF H W FISCHER) DIVISION OF DIAGNOSTIC RADIOLOGY
UNIVERSITY OF ROCHESTER SCHOOL OF MEDICINE AND DENTISTRY STRONG ME-
MORIAL HOSPITAL ROCHESTER NY 1464 U S A

THREE DIMENSIONAL SELECTIVE ANGIOGRAPHY IN THE DIAGNOSIS OF RENAL MASSES

V HEGERDUS

The aim of the present communication is to evaluate the advantage of three dimensional selective angiography of the kidney in the diagnosis of renal masses. This method has been used earlier for estimation of the *in vivo* volume of the kidney and its cortical volume and for the demonstration of the arterial anatomy of the kidney (HEGERDUS 1972, HEGERDUS & FAARUP 1972, HEGERDUS & RAYNSHOV 1972).

The material consists of proven cases of kidney cysts and tumours examined at the Department of Diagnostic Radiology Lund between 1970 and 1972 (38 patients) and at the Department of Diagnostic Radiology Strong Memorial Hospital between 1972 and 1973 (23 patients). In 61 patients 63 kidneys with mass lesions were examined. The cases represent 37 kidneys with solitary or multiple cysts and 26 kidneys with tumours; in one of the latter both tumour and cyst being present. The 36 male and 25 female patients were between 38 and 77 years of age and in fairly equal distribution.

Submitted for publication 27 March 1973

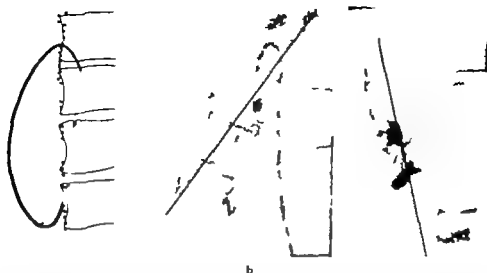


Fig. 1. The ventral-dorsal open angle (V-D angle). a) The angle is formed by the intersection of the long axis of the kidney and a line drawn from the anterior edge of the vertebrae immediately adjacent to the upper and lower poles of the kidney. In normal material this angle varies between 0 degrees and 4 degrees. The majority of normal kidneys have a V-D angle between 0 degrees and 1 degree (Hegedus 1972). b) Tumour in right kidney involving the dorsal lower portion. V-D angle 35 degrees. c) Tumour in right kidney involving the dorsal part of kidney. V-D angle inverse 22 degrees.

Method. In all cases aortography preceded the examination. The three-dimensional elective angiography according to previous publications (Hegedus 1972) was performed as follows.

Through a thin-walled catheter 8 to 14 ml of contrast medium was injected with the aid of an injector. The speed of injection was 10 ml per second. A small angiography was first made in the anterior-posterior projection followed by a series in the true lateral position of the kidney for demonstration of the ventral and dorsal surfaces. This position was obtained as follows. The patient was placed on the ipsilateral side. With the aid of fluoroscopy during the injection of approximately 5 ml of medium into the renal artery slight rotation dorsally gave a true lateral position for that kidney. The films obtained in both projections should include the early arterial, arteriolo-capillary, nephrographic and venous phases.

Evaluation of the films included in the lateral projection also measurement of the ventral-dorsal open angle (V-D angle) between the sagittal axis of the kidney and that of the body (Fig. 1).

The diagnoses were confirmed in the cyst material by puncture aspiration and histologic examination of the fluid. In addition the cysts were filled with



FIG. 2. Female, aged 68, admitted for flank pain on right side. (a) A.p. projection: no changes. (b) Lateral projection: cyst 5.5 cm in diameter, the central middle portion of the kidney.

contrast medium and radiologically examined. All patients in the tumour group were operated upon and the diagnoses confirmed by pathology. Autopsy was performed in two cases.

Results

The V—D angle measurements presented great variations as compared with the normal angles. In 38 cases (60 per cent) depending on the site of the mass lesion severe distortion of this angle was registered, the extremes being 42 degrees and inverse 24 degrees (Fig. 1). Of the remaining 25 cases (40 per cent) where the V—D angle was within normal limits 17 kidneys had cysts and 8 tumours.

In 37 cases (23 cysts and 14 tumours) the three-dimensional angiography resulted in exact localization of the lesion in relation to the adjacent tissues. In the remaining 26 cases (14 cysts and 12 tumours) the method used resulted in even greater diagnostic advantages as follows:

Cysts. In 8 cases the cyst was only demonstrated in the lateral projection (Figs 2, 3, 4) and in 2 cases this projection revealed additional cysts. In 3 cases only



Fig 3 Female aged 56. Incidental finding of left renal mass. Urography for hypertension. a) A/P projection: no mass lesion recognizable. b) Lateral projection: cyst adjacent to middle portion of the kidney.

the combination of the two projections allowed for clear differentiation between cyst and tumour (beak effect only in the lateral view). In one case the three dimensional method revealed severe distortion and compression of the perirenal structures (Fig 5).

Tumours. The selection of the surgical approach (flank or transperitoneal incision) was dependent on the three dimensional information in 9 cases. In 6 cases avascular mass lesions in the retrorenal space, i.e. the presence of lymph node metastases, were inferred (Figs 6-7). In 3 cases no mass lesions in the retrorenal space were demonstrated and on operation there was no evidence of metastases in regional lymph nodes. In 4 cases involvement of other organs (peritoneum, colon, diaphragm, pericardium, ribs) was suggested and confirmed at surgery (Figs 7-8). In one case (Fig 9) the vascular anatomy of the tumour in a solitary kidney was precisely described, thus allowing enucleation of the tumour.

Four representative cases from the tumour material may be presented.

Case 1. Female aged 62 admitted with chief complaint of episodes of gnawing pain in the right abdomen and flank. *Urography.* A large rounded mass at the lower pole of the

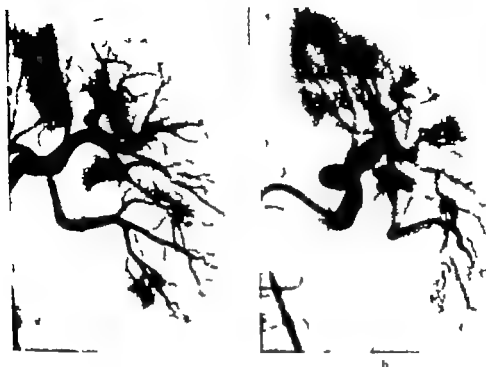


Fig 4 Female aged 68. Incidental finding of left renal mass. Angiography for hypertension. a) Ap projection, no abnormality. b) Lateral projection, cyst in lower dorsal portion of the kidney. V—D angle slightly increased to 26 degrees.

right kidney with no evidence of obstruction to draining structures. *Angiography* (Fig 6). A round poorly vascularized tumour at the lower dorsal portion of the kidney. Severe distortion and anterior displacement of the kidney and renal pelvis indicated extensive tumour growth in the retrorenal space. *Operative*: Transperitoneal approach. Right radical nephrectomy. Additional mass underneath the renal pelvis at the level of the renal pedicle and enlarged lymph nodes cranial of the origin of the renal artery. *Pathology*: Adenocarcinoma with extensive necrosis, renal involvement and metastases in the regional lymph nodes. Unremarkable postoperative course. Radiation therapy.

Case 2 Male aged 69 admitted with history of cough, fever and weight loss. Chest film revealed multiple metastases in both lungs. *Angiography*: A mass in the right kidney. *Angiography* (Fig 7). A richly vascularized round well-demarcated tumour in the right kidney with anterior extension and possible peritoneal involvement. The displacement of the renal pelvis and axis of the kidney indicated retrorenal involvement. *Operative*: Transperitoneal approach. Right nephrectomy. Tumour involvement of the peritoneum and the serosa of the colon. Enlarged regional lymph nodes. *Pathology*: Moderately differentiated renal cell carcinoma. Tumour growth in the regional lymph nodes. Involvement of the serosa of the ascending colon. Unremarkable postoperative course. Radiation therapy.



Fig 5 Female aged 47 admitted for right flank pain and palpable abdominal mass a) A/p projection ascula mass with 18 cm maximal diameter distorting and displacing right kidney b) midline Obstructed renal vein outlined by contrast medium b) Lateral projection large cyst arising from ventral surface of kidney With the patient in this position the renal vein patent although obstructed and the inferior vena cava (arrow) is demonstrated kidney displaced between vena cava and spine

Case 3 Male aged 66 admitted with history of weight loss fatigue and palpable left abdominal mass Blood chemistry revealed severe anemia and mild icterus *Urgey ph* A large mass involving the lower portion of the left kidney *Intrige ph* (Fig 8) A large infiltrating tumour involving the lower portion of the left kidney and the retro and retroperitoneal spaces Shunting between the renal and inferior mesenteric vessels and direct tumour growth into ribs 11 and 12 *Operation* En bloc nephrectomy splenectomy segmental colectomy and pancreas resection Death 4 weeks after the operation with perforated gastric ulcer *Nebraska septucentia and severe cardiac failure Pathol gy and aut psy* Infiltrating anaplastic sarcoma or lymphoma involving the kidney dorsal abdominal wall tail of the pancreas spleen peritoneum and descending colon

Case 4 Female aged 63 admitted with sole complaint of hematuria Four years before this admission right nephrectomy for carcinoma Multiple subsequent negative metastatic survey On admission microscopic hematuria only abnormal finding *Urgey ph* Distortion of the calyces in the middle portion of the solitary left kidney *Metastatic survey* Negative *Urgey ph* (Fig 9) No recurrence at the site of the previous operation Small round tumour in the mid dorsal portion of the left kidney mainly supplied by one branch of the

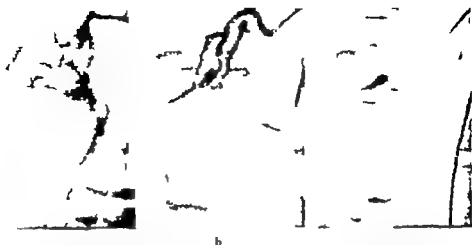


Fig 6 Case 1 Right kidney. a) A-p projection large cyst like mass distally in the severely distorted kidney. b) Lateral projection the mass lesion arises from dorsal middle portion of kidney and displaces its lower pole cranially. The lesion has thick secular wall towards the kidney (arrow) and is supplied dorsally by few abnormal vessels. In addition the entire kidney is displaced cranially. Artery from tumour directed into the retrorenal space. c) Lateral projection venous phase displays mass draining the tumour and severe ventral dislocation of the main renal vein (arrow).



Fig 7 Case 2 Right kidney. a) A-p projection large tumour medially. b) Lateral projection tumour protrudes dorsally towards peritoneum. Despite this ventro-dorsal angle is 90 degrees. Furthermore the upper part is attached to the tumour resulting in ventral dislocation. No indication of mass in retrorenal space. Ventral displacement of main renal vein (arrow) suggests enlargement of lymph nodes.

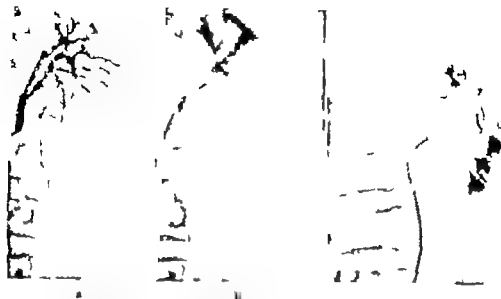


Fig 8 Case 3 Enlargement of left kidney. A-p projection in arterial (a) and venous (b) phases: large diffusely growing tumour with venous return through inferior mesenteric artery indicating tumour infiltration of descending colon. (c) Lateral projection: extensive growth in retrorenal space with infiltration of the two lower ribs.

main renal artery. Separate venous drainage from the tumour. No abnormalities suggesting infiltration of other parts of the kidney or extrarenal tissues. **Operation:** Easy identification and clamping of the supplying and draining vessels followed by injection of methylene blue into the arterial branch supplying the tumour. Excision of the demarcated tumour with small margins in normal kidney tissue. Lymph node biopsies. **Pathology:** Moderately differentiated renal cell carcinoma surrounded by compressed fibrotic renal tissue. No evidence of lymph node metastases. **Postoperative course:** Mild transient anemia (serum creatinine 3.0 mg %) for 2 weeks. Urinary fistula at the skin closed spontaneously after 4 weeks. After further 4 weeks of full-time work in her earlier occupation.

Discussion

Angiography of the kidney is now routine in the investigation of renal masses. In spite of the nonspecificity of abnormal vascularity of malignant neoplasms (VIAHOMTE et coll 1973) pharmacologic interventions may enhance the accuracy of the procedure (ABRAMS 1964; CARO et coll 1969; EDELUND et coll 1972).

Further improvement in diagnostic accuracy has been achieved by needle aspiration of avascular renal lesions (LINDBLOM 1946; THORNBERG 1972). False-negative cyst punctures, i.e. failing to detect occult tumour in the cyst wall, are



Fig. 9 Case 4 Solitary left kidney. a) AP projection small renal vein draining middle portion of kidney. Early filling of small vein draining the tumor is seen. b) Tumor located distally in the kidney. The tumor is primarily in the first primary branch of the renal artery. Such has extrarenal origin. Three lumens are visible in the lateral projection. This is essential for planning excision of the tumour with minimum loss of parenchyma.

fortunately very uncommon but a few cases have been published (Itami et coll 1961, BARTLEY & HELANDER 1962, BRANNAN et coll 1962, KIMURA et coll 1963, WATSON et coll 1968). The three dimensional localization may yet further enhance the accuracy of needle placement with less damage to normal surrounding tissues. In the cases presented here all cyst punctures were successfully performed without late complications or discomfort for the patient. Most important however is the fact that in 8 out of 37 investigations cysts were detected only in the lateral projection (Figs 2, 3, 4). The largest cyst unrevealed in the AP view had a diameter of 6 cm. In one case two cysts clearly demonstrated in the lateral projection failed to be demonstrated in the AP view.

The lateral projection was instrumental in the detection of extension of tumour into the surrounding tissues and regional lymph nodes. In many cases tumour extension towards the anteriorly lying intraperitoneal structures (Fig. 7) or intrathoracic direct infiltrative growth were detected or infiltration of the retrorenal space (Figs 7, 8) suggested. In some cases (Figs 6, 7) displacement of the renal vein indicating growth of tumour in the area of the regional lymph nodes, was noted. To our knowledge no similar findings have been published. In the entire series false positive lymph node metastases were reported in two cases, while in three cases evident lymph node metastases at operation were not demonstrated. Case 4 is particularly interesting. The patient had already years before lost the contralateral kidney and the tumour occurred in the solitary kidney. The three dimensional angiography was necessary to define the exact site of the tumour, its arterial supply and venous drainage. Thus it was made clear before exploration that resection of the lesion was possible with maintenance of a sufficient amount of kidney parenchyma (Fig. 9).

Measurement of the V—D angle in the cyst material provided additional information about the possible displacements of the kidney caused by the adjacent space occupying lesion. However in the tumour material the displacement of the kidney and distortion of its axes were of essential diagnostic importance. In one of our cases, in addition to the increased V—D angle, the entire kidney was displaced ventrad, indicating besides the tumour an avascular mass lesion in the retrorenal space. In case 2 despite the anterior site of the tumour the V—D angle was increased which indicated that the displacement due to the tumour was more than compensated for by an even larger mass in the retrorenal space. In another case the entire kidney was displaced ventrad without distortion of the V—D angle indicating extensive tumour growth in the retrorenal space.

It seems that the appreciation of an abnormal V—D angle has the most important diagnostic significance when unexpected, as it would indicate an additional avascular mass lesion prohibiting a logical displacement of the kidney.

Although renal masses are successfully examined by nephrotomography (EVANS *et coll.* 1955), ultrasound (GOLDBERG *et coll.* 1968), isotope scanning (ROSENTHALL 1966), angiography (FOLIV 1967) and pharmacangiography (ABRAMS 1964; EKLUND *et coll.* 1972), three dimensional angiography gives additional information not derivable from the other techniques. The ventral and dorsal surfaces of the kidney are demonstrated, the vessel distortions and displacements recognizable only in the third dimension, the antero- and retrorenal spaces and an abnormal position of the kidney can be truly defined only by three dimensional angiography, but usually no increased information about the vascularity of the lesion is obtained. However the information may approach a qualitative level, which may be decisive when selecting the proper therapy.

SUMMARY

Three dimensional angiography of the kidney may enhance information derived from conventional two dimensional angiography. The vascular topography of renal mass lesions is better defined, the distortion of the position of the kidney is determined and the antero and retrorenal spaces may be investigated.

ZUSAMMENFASSUNG

Die dreidimensionale Angiographie der Niere kann die von einer herkömmlich zweidimensionalen Angiographie erhaltene Information erhöhen. Die vaskuläre Topographie expandierender Nierenprozessen ist besser definierbar, die Distorsion der Lage der Niere besser bestimmbar und die anterioren und retrorenalen Abschnitte lassen sich untersuchen.

RESUMÉ

L'angiographie tridimensionnelle du rein peut compléter les informations obtenues par l'angiographie bidimensionnelle ordinaire. La topographie vasculaire des lésions tumorales rénales est mieux définie, les modifications de la position du rein sont précisées et on peut examiner les espaces pré et rétrorenaux.

REFERENCES

- VARANS H L. The response of neoplastic renal vessels to epinephrine in man. *Radiology* 82 (1964) 217.
- BARTLEY O and HELANDER C G. Angiography in spontaneously healed hypernephromas. *Acta radiol. Diagn.* 57 (1962) 417.
- BELMANN W, MILLER W and GUNDEL M. Coexistence of renal neoplasms and renal cysts. *Sth. med. J.* 55 (1962) 749.
- CARO C, MERRILL R and HELD B. Epinephrine enhanced arteriography in renal and perirenal abscess. A differential diagnostic problem. *Radiology* 92 (1969) 1262.
- FISKELAND L, GOTHLYF J and LINDERQUIST A. Diagnostic improvement with angiotensin in renal angiography. *Radiology* 105 (1972) 33.
- ELIAS J A and BORTOLINI M A. The kidney. An atlas of tumor radiology. Edited by P J Hodges. Year Book Medical Publishers Inc. Chicago 1971.
- , MONTGOMERY J C and DUBILIER JR W. Nephrotomography. *Radiology* 64 (1955) 635.
- FOUR J. Angiography in renal tumours. Its value in diagnosis and differential diagnosis as complement to conventional methods. *Acta radiol.* (1967) Suppl. No 267.
- GOLDNER B B, OSTRUM B J and ISARD H J. Nephrosonography. Ultrasound differentiation of renal masses. *Radiology* 90 (1968) 1113.
- HAROLDUS V. Three-dimensional estimation of renal shape and volume. *Acta radiol. Diagn.* 12 (1972) 87.
- , Arterial anatomy of the kidney. A three-dimensional angiographic investigation. *Acta radiol. Diagn.* 12 (1972) 604.
- and FAARUP P. Cortical volume of the normal human kidney. Correlated angiographic and morphologic investigations. *Acta radiol. Diagn.* 12 (1972) 481.
- and RAABER U. Cortical volume in apparently normal kidneys. *Scand. J. Urol. Nephrol.* 6 (1972) 159.

- ALDERAND D.: Carcinoma within solitary renal cysts. *J Urol* 93 (1965) 440
- LAO E. K.: Roentgenographic diagnosis of renal mass lesions. Published by W. H. Green Inc. St. Louis 1971
- : The accuracy of roentgenographic techniques in the diagnosis of renal mass lesions. *Radiology* 98 (1971) 119
- LINDBLOM K.: Percutaneous puncture of renal cysts and tumors. *Acta radiol* 27 (1946) 66
- LJUNGBERG E.: Partial nephrectomy in renal tumor. *Acta chir scand* (1960) Suppl. 253 p. 37
- REIF R. A., TALOR W. N. and TAYLOR J. N.: Renal cyst associated with carcinoma. *J Urol* 86 (1961) 307
- ROSENTHALL L.: Radionuclide diagnosis of renal cysts and neoplasms using the gamma scintillation camera. *J Canad Ass Radiol* 17 (1966) 85
- VON SCHIRREN T., ARNER O., SAOVEDRA G. and N. WIDSTAD: Renal adenocarcinoma: is there a risk of spreading tumor cells in diagnostic puncture? *Scand J Urol Nephrol* 1 (1967) 270
- THORNBURY J. R.: Needle aspiration of a vascular renal lesions. *Radiology* 105 (1972) 799
- VIAMONTE JR. M., SKELDON R. and LEPAGE J.: Nonspecificity of abnormal vascularity in the angiographic diagnosis of malignant neoplasms. *Radiology* 106 (1973) 59
- WATSON R. C., FLECKNO R. J. and EVANS J. A.: Arteriography in the diagnosis of renal carcinoma: review of 100 cases. *Radiology* 91 (1968) 888

ANGIOGRAPHY IN COLLAGENOUS DISEASE OF THE KIDNEY

L. EKKLUND and T. LINDBOLM

Reports on the angiographic findings in collagenous disease of the kidney are sparse most of them dealing with polyarteritis nodosa (BRON *et coll* 1965 FLEMMING & STERN 1965 CRUDACKER 1966 1967 ERFEN & LORENZEN 1968 McCLEURE & WESTCOTT 1969 ROBINS & BOORSTEIN 1972) Vascular abnormalities of the kidney in two cases of scleroderma with renal failure were published by LESTER & KOEHLER (1971) No reports on angiography in systemic lupus erythematoses can be traced As abnormalities may be marked it seemed worth while to analyze the angiographic findings in a series of patients with collagenous disease of the kidney and also to try to relate these to the clinical signs and stage of the disease

Material and Methods The material consisted of 6 patients with systemic lupus erythematoses (SLE) 2 with polyarteritis nodosa, 1 with progressive systemic sclerosis (scleroderma) and 1 patient with Wegener's disease The ages and clinical diagnoses are given in Table 1 all the patients with SLE were women The patients were examined by transfemoral bilateral selective angiography of the kidneys in nine instances preceded by abdominal aortography

Submitted for publication July 1973

Table 1

Age sex diagnoses and clinical findings in the present material

Case	Age	Sex	Diagnosis	Serum creatinine mg (time of angiography)	Blood pressure mm Hg	Anti- hyper- tensive therapy
1	50	F	SLE	0.8	190	No
	37	F	SLE	0.8	150/90	No
3	3	F	SLE	0.65	150/95	No
4	1	F	SLE	2.6	140/80	No
	1	F	SLE	1.7	140/90	No
5	70	F	SLE	1.9	140/90	Yes
	56	M	Polyart nodosa	5.1	140/5	No
8	7	M	Polyart nodosa	0.83	165/110	No
9	4	F	Scleroderma	18.0	160/100	Yes
10	2	M	Wegener disease	1.2	110/75	No

The angiograms were evaluated according to the following criteria: kidney size, calibre of main renal artery, appearance and filling of intrarenal arteries and cortical width and definition of the boundary between the cortex and medulla as well as the renal circulation time and demonstration of the renal vein.

The renal function was reduced in 2 patients with SLE. One of these (Case 6) was admitted to the clinic for the first time in 1965 with oliguria. She was treated with haemodialysis four times before diuresis was obtained by corticosteroids. Angiography of the kidneys was performed in 1968. Cases 7 and 9 were admitted because of oliguria. Case 7, the man with polyarteritis nodosa, improved during immunosuppressive therapy, but the woman (Case 9) with scleroderma died some weeks after the angiography.

Elevated blood pressure (160/100 or more) was recorded in 2 patients, one of whom was under antihypertensive therapy; the blood pressure in a further patient on antihypertensive drugs was normal (Table 1).

The clinical diagnoses were confirmed by renal biopsy in 7 patients. Three patients (Cases 5, 7, 9) died.

Case reports

Case 1. Woman, aged 51, who for two years had had three episodes of fatigue, subfebrility and muscle and joint pains. A serum creatinine concentration of 4.0 mg per cent led to her admission. She had proteinuria of the glomerular type and the urinary sediment in each visual field contained more than 20 red blood cells and occasional granular cast.



Fig 1 Case 4 Systemic lupus erythematosus. Selective arteriography of the right kidney. 1) tertiary arteries narrowed towards the periphery. Non-filling of interlobular arteries and indistinct boundary between cortex and medulla. 2) Arterial b) nephrographic phase

Urography was normal. Fibrin degradation products were present in the serum but not in the urine. Renal biopsy revealed advanced glomerular changes: the arteriolar walls were hyalinized and fibrinoid necrosis was also evident. The appearances were considered consistent with chronic glomerulonephritis possibly on the basis of collagenosis.

Angiography: kidney of normal size. The cortical arteries were not filled and the boundary between the cortex and medulla was indistinct (Fig 1).

The findings of products of fibrin degradation in the serum suggested intra-venous heparin treatment: this was given for 8 days without any obvious effect. Treatment with corticosteroids was instituted 2 weeks later. The general condition of the patient then rapidly improved although renal function was still reduced with the serum creatinine about 2 mg per cent.

Earlier muscle biopsy had revealed normal conditions but biopsy six months later of a superficial ulcer of the tip of the right ear disclosed intradermal vasculitis compatible with collagenosis. The treatment with the steroids failed to alter the degree of proteinuria. The blood pressure as well as the ocular fundi were normal throughout.

Case 7: A 35-year-old male with bronchial asthma from youth had seven months previously noticed that his legs were swollen. The haemoglobin was 8.8 g per cent, the ESR 148 mm per h and the proteinuria 0.3 per cent. Anti streptolysin titre and antistreptolysin factors were positive. During the first month of observation the serum creatinine concentration rose from 2 mg to 10 mg per cent. The blood pressure was normal. Renal biopsy revealed advanced necrotizing diffuse glomerulonephritis and vasculitis of the fibrinoid type: the latter was also evident in the vessels from muscle biopsy.

Angiography: Enlarged right kidney, normal size of left kidney. Narrowing of interlobular arteries and non-filling of interlobular arteries. Indistinct boundary between the cortex and medulla. No infarction and no arterial aneurysms.

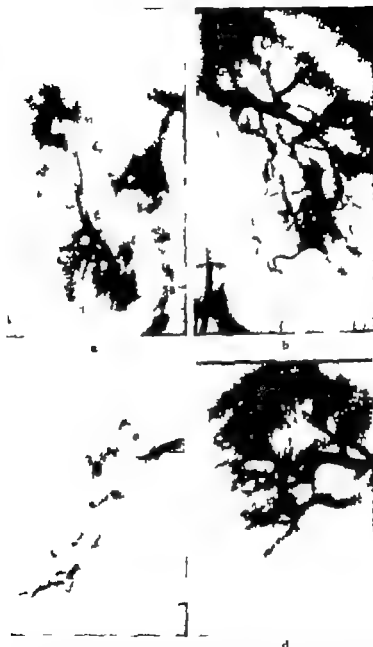


Fig 2 Case II Polyarteritis nodosa. a) Left kidney. Selective angiography. Insufficient filling of ventral artery. Dorsal artery appears normal. b) Left kidney 12 months later. Widespread aneurysms have developed in ventral as well as dorsal artery. Collateral circulation in lower capsular artery. c) Right kidney. Stenotic dorsal artery most marked in proximal part. It fractures laterally in lower pole. d) Right kidney 24 months later. Dorsal artery almost occluded 1 cm from origin.



Fig 3 Case 8 Superior mesenteric angiogram. Stenosis of coeliac artery with collateral circulation in pancreatic arcades. Irregular stenoses in main stem of superior mesenteric artery distal to ileocolic artery (\rightarrow) 3 cm long occlusion of one ileal artery. Much fills in collaterals ($\rightarrow\rightarrow$)

The patient was given prednisolone initially 75 mg per day and azathioprine 150 mg per day. The renal function improved and the serum creatinine decreased to 1.6 mg per cent. One year later the renal function was essentially unchanged but later on it deteriorated again and the patient died in spite of the immunosuppressive treatment.

Case 8. Man aged 27 who had had intermittent attacks of fever and joint pains for 1½ years was admitted with anaemia, an ESR of 60 mm/h and considerable loss of weight. An extensive examination including angiography performed about four months previously had produced no definite diagnosis (Fig 2). About this time arterial hypertension developed and as this was drug resistant a further examination was carried out.

The ocular fundi had hypertensive changes grade III Keith Wagener and antinuclear factors were now revealed with the fluorescent technique. Further angiography of the kidney disclosed multiple arterial stenoses (Fig 2b). Renal biopsy indicated that some glomeruli were almost hyalinized, an increased number of cells and thickened basal membrane were evident in others. The microscopic appearances were consistent with subcuticular glomerulonephritis but considering the other clinical findings the patient was labelled as having arteritis.

Further angiography after another two years demonstrated progression of the arterial changes in the right kidney but no changes on the left side (Fig 2d). Superior mesenteric angiography was also performed at this time and demonstrated marked vascular changes (Fig 3).

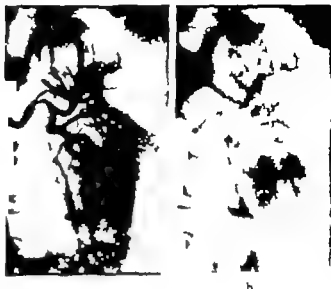


Fig. 4 Case 9 Scleroderma. Selective angiography of left main renal artery. (The kidney is also supplied by lower pole artery.) Stenosis of main stem (confirmed at previous orthography). Multiple irregular arterial stenoses and prolonged circulation time. (regular kidney surface). Early b) late phase.

Immunosuppressive treatment was started with azathioprine 150 mg and prednisolone 15 mg daily in addition to antihypertensive therapy. The clinical condition of the patient improved remarkably. The steroid therapy was withdrawn but azathioprine is still being given (July 1973). The blood pressure is also under control at the moment with a β blocking agent (Inderal 280 mg daily), betanidine (Esbatal 40 mg daily) and hydrochlorothiazide (Eudrex 25 mg daily). The eye-ground changes have regressed and are now grade I Keith-Wagener. The renal function measured as endogenous creatinine clearance has always been normal in spite of the changes evident at angiography as well as at biopsy. The general condition of the patient is excellent and he is working full time.

Case 9. Woman aged 45 with tenosynovitis in both wrists for 9 months and hyperpigmentation with the leg and the forearm similarly affected for 3 months. Biopsy of the skin disclosed certain abnormalities indicating scleroderma. Treatment with steroids was instituted. A few weeks later she was admitted after a grand mal convulsion. The blood pressure previously normal was 210/130 mm Hg. The fundi had hypertensive changes grade IV Keith-Wagener.

Angiography. Stenosis of both main renal arteries. Multiple irregular intrarenal artery stenoses and prolonged circulation time. Irregular kidney surface (Fig. 4).

The blood pressure was brought down to almost normal with dihydralazine (Nepresol) and betanidine (Esbatal) but despite this the patient had signs of cardiac failure with incipient pulmonary oedema. The amount of urine excreted gradually decreased, uremia supervened and peritoneal dialysis was inaugurated. The general condition of the patient deteriorated however and she died three weeks after admission.

Autopsy revealed collagenous disease of the type progressive systemic sclerosis. Multiple small cortical infarctions were present in the kidney. The intima of the small and middle sized arteries was hyperplastic and thickened as occurs in malignant nephrosclerosis.

Table 2

Angiographic findings in 10 cases of collagenous disease of the kidney

Case	Diagnosis	Kidney size	Renal artery			Cortical ad h	Boundary between cortex and medulla
			Main stem	Interlobar arteries	Interlobular arteries		
1	SLE	Normal	Normal	Normal	Normal	Normal	Distinct
2	SLE	Normal	Normal	Nontapering	Normal	Normal	Distinct
3	SLE	Left slightly reduced	Normal	Normal	Nonfilling	Localized reduction	Indistinct
4	SLE	Normal	Normal	Normal	Nonfilling	Slightly reduced	Indistinct
5	SLE	Increased	Normal	Slightly widened	Nonfilling	Normal	Indistinct
6	SLE	Decreased	Normal	Narrowed	Nonfilling	Reduced	Indistinct
7	Polyart nodosa	Normal left Increased right	Normal	Narrowed	Nonfilling	Reduced	Indistinct
8	Polyart nodosa	Normal (infarct)	Normal	Stenoses and occlusions	Reduced filling	Infarctions	Indistinct
9	Sclero- dema	Normal	Stenoses	Tortuous and irregular	Nonfilling	Reduced	Indistinct
10	Wegener disease	Normal	Normal	Normal	Normal	Normal	Normal

The angiographic findings in the 10 patients with collagenosis appear in Table 2. The angiography was normal in one of the 6 patients with systemic lupus erythematosus—all women—and one patient had only minor pathologic changes in the form of somewhat widened interlobar arteries that were non-tapering. The remaining 4 patients had one characteristic in common: nonfilling of interlobular arteries and an indistinct boundary between the cortex and medulla. Two of these patients had kidneys of normal size. In one 71-year-old woman with acute exacerbation of the disease the kidneys were swollen and the intrarenal arteries widened and stretched while in another case of longstanding disease the kidneys were shrunken. The renal vein was always patent.

Both patients with polyarteritis nodosa had vascular abnormalities ranging from narrowing and irregularity of peripheral interlobar arteries and nonfilling of arcuate and interlobular arteries to marked irregularities and even occlusions of more proximal arteries with ensuing infarctions of the kidneys. Arterial aneurysms were not encountered.

The most advanced vascular abnormalities occurred in an uremic patient with progressive systemic sclerosis. Finally in the 52-year-old man with Wegener's



Fig 5 Angiogram of the left kidney in an old man with reduced renal function. Stenoses and aneurysmatic dilatation of intra renal arteries suggesting collagenous disease. Autopsy revealed only bilateral arteriosclerosis. (The patient died from prostatic carcinoma.)

diabetes and pulmonary involvement but with normal renal function angiography was normal. Renal biopsy demonstrated marked glomerular changes but only suggested the presence of vasculitis.

Discussion

Connective tissue alterations are characteristic features in collagenous disease (KLEMPERER 1950). This includes SLE, polyarteritis nodosa, scleroderma, Wegener's disease and rheumatoid arthritis.

The degenerative changes in SLE occur in the glomeruli thus resembling glomerulonephritis. The angiographic findings were therefore of the same type as described in glomerulonephritis where impaired filling of interlobular arteries and an indistinct boundary between the cortex and medulla are fairly common (EKLUND *et coll.* 1973). Similar changes may also occur in renal amyloidosis, although in the latter interlobar arteries are usually also involved (EKLUND & LINDHOLM 1974).

Polyarteritis nodosa is a systemic disease characterized by fibrinoid necrosis of the vessel walls. Renal involvement is reported in about 80 per cent of the cases (DAVISON *et coll.* 1948, ROSE 1957). These vascular lesions may lead to arterial occlusions and subsequent infarctions of the kidneys. The findings at nephro-

angiography have been described. CHUDACEK (1966) and FRSEN & LORENZEN (1968) reported one case each with rarefaction of peripheral arteries and heterogenous nephrography. Multiple aneurysms of intrarenal arteries have been described by FLEMING & STERN (1965), BROWN *et coll* (1965), CHUDACEK (1967), McCURRY & WESTCOTT (1969) and ROBINS & BOOKSTEIN (1972). These aneurysms may be transitory in nature and regress as described in the two last mentioned reports. In neither of the present 2 cases were aneurysms demonstrated. In one case, however, marked vascular changes with arterial irregularities and occlusions with ensuing infarctions of the kidneys occurred. Progression could be demonstrated at repeat angiographies. Superior mesenteric angiography in this case also demonstrated stenoses and occlusions of intestinal arteries. Vascular changes in the mesentery in polyarteritis nodosa have previously been reported by RABINOVITCH & RABINOVITCH (1954), POOR & STRAUSS (1956) and CHUDACEK (1967).

Arterial changes in the extremities in scleroderma have been described by VOGLER & GOLLMANN (1953) and by SCHÖBER & KILIAN (1966). Renal vascular changes demonstrated at angiography it would appear have been described only in 3 cases so far: 2 by LESTER & KOEHLER (1971) and 1 by GROLLMAN *et coll* (1970). The findings of LESTER & KOEHLER, i.e. irregular arterial narrowing, tortuosity of intrarenal arteries, prolonged circulation time and poor nephrographic effect were the same as in the present case, which also had stenoses of both main renal arteries. The statement of these authors that the development of renal signs in patients with scleroderma is quickly followed by death would seem true even in the present instance.

It is thus evident that with some progression of the renal disease in collagenosis marked vascular changes may be an important feature. From the differential diagnostic point of view similar changes may occur in arteriosclerosis of the kidney (Fig. 5) but are usually less prominent.

SUMMARY

The angiographic findings in 10 patients with collagenous disease of the kidney are presented. In systemic lupus erythematosus they were of the same type as may occur in glomerulonephritis. The most advanced vascular changes were evident in one case of polyarteritis nodosa and in one of scleroderma.

ZUSAMMENFASSUNG

Die angiographischen Befunde bei 10 Patienten mit einer Kollagenose der Nieren werden beschrieben. Diese waren bei dem generellen Lupus erythematosus von gleichem Typus wie bei der Glomerulonephritis auftreten konnten. Die am stärksten fortgeschrittenen vaskulären Veränderungen lagen in einem Fall an Polyarteritis nodosa und in einem an Scleroderma vor.

RÉSUMÉ

Présentation des résultats angiographiques chez 10 patients atteints de maladie du col lège à localisation rénale dans le plus systématique systématique ces signes étaient du même type que ceux qui peuvent exister dans la glomérulonéphrite. Les modifications les plus avancées ont été trouvées dans un cas de polyartérite noueuse et dans un cas de sclérodémie.

REFERENCES

- BROWN H. M., STROTT C. A. and SHAPIRO A. P. The diagnostic value of angiographic observations in polyarteritis nodosa: a case of multiple aneurysms in the vascular organs. *Arch. Int. Med.* 116 (1965) 450.
- CITRONCEK Z. Zum Röntgenbild der Periarthritis nodosa der Niere. *Fortsch. Röntgenstr.* 10 (1966) 49.
- Angiographic diagnosis of polyarteritis nodosa of the liver, kidney and mesentery. *Brit. J. Radiol.* 40 (1967) 864.
- DANFORTH B. L. J. and LATT R. Kidney in periarthritis nodosa. *Quart. J. Med.* 17 (1918) 175.
- EKLUND L. and LÖNNERZ L. Nephroangiography in periarthritis nodosa. *Acta radiol. Diagn.* 9 (1968) 225.
- EKLUND L. and LINDHOLM T. Angiography in renal amyloidosis. *Acta radiol. Diagn.* 15 (1974) 393.
- KATZ J. and LINDHOLM T. Angiography in glomerular disease of the kidney. A correlation with clinical findings and the stage of the disease. *Amer. J. Roentgenol.* 119 (1973) 739.
- LEWIS H. J. and STERN L. Z. Multiple intraparenchymal renal aneurysms in polyarteritis nodosa. *Radiology* 84 (1965) 100.
- CRONIN JR. J. H., LACKY J. W. and ROSS J. Miscellaneous diseases of arteries or of arterial lesions aren't fatty. *Semin. Roentgenol.* 5 (1970) 306.
- KLEMPERER I. The concept of collagen diseases. *Amer. J. Path.* 26 (1950) 505.
- LESTER I. D. and KORTLE P. R. The renal angiographic changes in scleroderma. *Radiology* 10 (1971) 517.
- MCCARTHY H. and WESTCOTT J. L. Periarthritis nodosa with perirenal hemorrhage: a report with angiographic findings. *J. Urol.* 102 (1969) 126.
- PETER J. I. and STRANGE I. Abdominal periarthritis nodosa. *Brit. J. Surg.* 44 (1956) 30.
- RABINOWITZ J. and RABINOWITZ S. Infarction of small intestine sequelae in polyarteritis nodosa of the mesenteric vessels. *Amer. J. Surg.* 88 (1951) 806.
- ROBIN J. M. and BOOKSTEIN J. J. Regressing aneurysms in periarthritis nodosa. *Radiology* 104 (1972) 39.
- ROSS C. A. The natural history of polyarteritis. *Brit. med. J.* 2 (1957) 1148.
- SCHÖNBERG R. and KLEMPERER I. Angiographische Befunde bei Scleroderma progressiva. *Fortsch. Röntgenstr.* 10 (1966) 239.
- VOCIT F. and COLLIN W. G. Über angiographisch nachweisbare Effortsänderungen bei Scleroderma diffusa. *Fortsch. Röntgenstr.* 78 (1953) 379.

LUNG AERATION IN THE FULLTERM NEWBORN RABBIT

Roentgenologic and histologic investigations

GERTIL GROSSMANN B LAMKE and B ROBERTSON

The adaptation of the fetal mammalian lung to extra uterine life involves a series of events which must be smoothly coordinated to ensure the survival of the newborn. Vigorous respiratory movements are required in the initial phase of lung aeration to overcome the surface forces in the peripheral airspaces particularly in individuals with inadequate amounts of surfactant phospholipids in the pulmonary fluid. Furthermore the pulmonary vascular resistance must decrease to enhance the pulmonary blood flow and the lymphatics of the lungs must begin to remove interstitial pulmonary fluid. Under normal circumstances a favourable ventilation perfusion relationship is quickly established but in case of pulmonary prematurity the aeration and perfusion of the lungs are frequently hampered leading to a condition known clinically as the idiopathic respiratory distress syndrome.

The purpose of the present investigation was to analyse the neonatal adaptation of the fullterm rabbit lung with roentgenologic and histologic techniques with particular reference to the aeration of the parenchyma in relation to the

Submitted for publication 12 June 1973

resorption of fetal pulmonary fluid. The results will serve as a basis for similar investigations on premature fetuses, in which tracheal deposition of surfactant phospholipids has been used as a prophylactic measure against neonatal respiratory distress (cf. ENHORNING & ROBERTSON 1972; ENHORNING et coll. 1973).

Material and Methods. The experiments were carried out on 44 nearly full-term rabbit fetuses: 24 for roentgenologic and histologic evaluation of lung aeration and 20 for determination of the wet weight of the lungs.

Pregnant female rabbits, whose time of mating was known within a range of two hours, were killed by intravenous injection of 5 ml 2M KCl after gestation 30 days less 2 to 6 hours (fullterm = 31 ± 1 days, mean \pm SD). The abdomen was opened and the upper part of the vagina clamped with a large hemostat. The fetuses were then delivered through random uterine incisions.

Four animals from each litter were used for roentgenologic examination. The respiratory movements were first prevented by the application of a rubber stall covering the mouth and the nose. The animals were then loosely affixed to a sheet of cardboard, by means of strips of gauze, and a first exposure made (a.p. projection only) within an average of 5 min (range 3.5 to 9 min) after the beginning of the surgical procedure. The rubber stalls were then removed simultaneously and a second analogous exposure was made 5 to 6 seconds after the first one. Further exposures were made at the following intervals: 10, 20, 30, 1, 2, 3, 4, 5, 10, 15, 30, 45, 60, 90 and 120 min after the removal of the rubber stalls.

Regular respiratory movements were observed in all fetuses within a few seconds after removal of the rubber stall and they all continued to breathe without apparent discomfort throughout the experiment. The fetuses were killed with intraperitoneal Nembutal 15, 30, 60 or 120 min after removal of the rubber stalls and the unopened thorax was fixed with formalin 10% for 1 week, then sliced transversally at the level of the cardiac ventricles and embedded in paraffin. From these blocks 10 μ thick microtome sections were cut and stained with hematoxylin and eosin.

In addition to routine microscopy, lung volume proportions were analysed morphometrically with an integrating eye piece of point-counting type (CHALALEY 1943). The relative volume (V) of the following two compartments was determined:

Alveolar lumen, alveolar and alveolar duct spaces, i.e. all airspaces distal to the terminal bronchioles.

Parenchyma, alveolar walls, pulmonary blood vessels and lymphatics, peribronchial and septal tissue and any other component of the lung which cannot be referred to as airspace lumen.

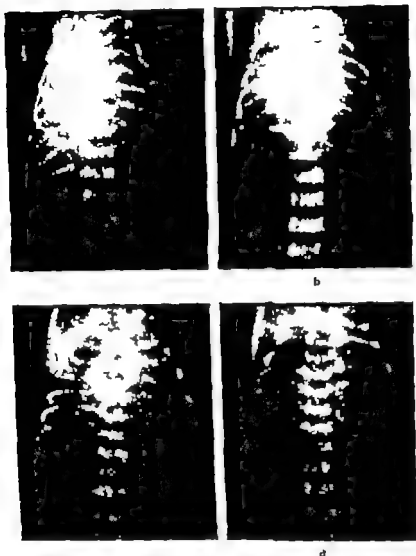


Fig. 1. Lung films from nearly fullterm rabbit fetuses before and after the first breath. $\times 2.5$. a) Before onset of breathing. No air below the trachea; the ribs are directed caudally. b) Six seconds after the removal of the rubber stall. The lungs seem to be completely aerated. c) Two min after the removal of the rubber stall. The upper ribs have assumed transverse position. d) Two hours after the onset of breathing. The ribs have assumed an intermediate position, consistent feature throughout the series. No further aeration of the lungs as compared with (b).

The entire transverse section of the lung was screened in each case and the degree of alveolar expansion was calculated as follows

$$\text{Alveolar expansion index} = \frac{V_{\text{alveolar lumen}}}{V_{\text{parenchyma}}}$$

Six additional fetuses were killed in utero and their lungs were analysed histologically using the morphometric method described above

In a separate series, 20 fetuses were killed with intraperitoneal Nembutal at the intervals 15 30 60 and 120 min after delivery. The thoracic cages were opened and the main bronchi were cut close to the lung parenchyma. After removal of the heart, the esophagus and the mediastinal tissue the lungs were weighed together and the ratio between the wet weight of the lungs and the body weight was calculated

Results

No air was found in the lungs on films obtained before the first breath (Fig 1 a). After the onset of breathing usually within 10 s after the removal of the rubber stalls a radiographically complete aeration of both lungs appeared. The fetal position of the ribs (cf Fig 1 a) did not change during this initial phase of aeration (Fig 1 b). During the following two minutes the thoracic volume seemed to increase gradually as estimated from the elevation of the upper ribs to transversal position (Fig 1 c). Later the ribs consistently assumed an intermediate position i.e. they were more elevated than before onset of breathing but deflected in comparison with the aforementioned transversal position (Fig 1 d).

In one animal no air could be observed in the parenchyma of the lungs until 30 seconds after removal of the rubber stall only the bronchi were air filled during the whole experiment (15 min). Another fetus, after 15 min of normal breathing had a transient period without aeration of the lungs lasting 15 min. On the subsequent films (45 min 1 h) there was a gradual transition to a normal appearance.

In lung sections from animals that had been killed before the onset of breathing the alveoli had the shape characteristic of the fluid filled state i.e. they were uniform in size and their walls were wrinkled (Fig 2 a).

In all animals killed after 15 min including the fetus with only the bronchi air filled there was a patchy air expansion of alveoli and alveolar ducts. Small areas of air filled somewhat overdistended alveoli and alveolar ducts with a rounded shape alternated with more extensive areas where the fluid filled alveoli had retained their fetal appearance (Fig 2 b). In many conducting airways

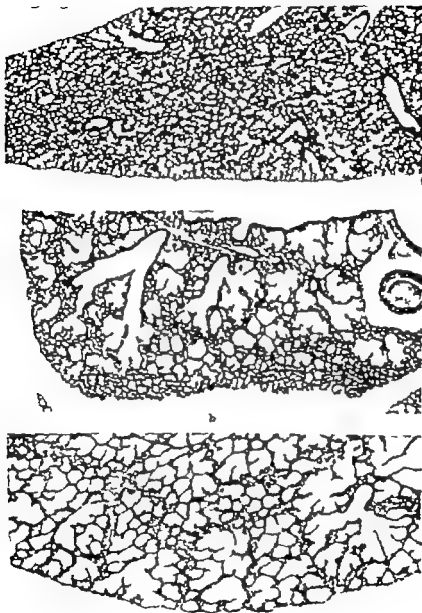


Fig. 2. Microscopy of lungs of a fully full-term rabbit fetus (gestational age = 30 days). Hematoxylin and eosin $\times 33$. Fetus killed in utero. The alveoli are uniform in size and the walls are wrinkled representing the fluid-filled state. Alveolar expansion index = 0.5.
 b) Fetus killed 15 min after delivery. Primary air expansion with local overdistension of alveoli and alveolar ducts alternating with unexpanded areas. Alveolar expansion index = 1.07.
 c) Fetus killed 2 h after delivery. The alveoli are more uniformly expanded with air, although fluid-filled areas still remain. Alveolar expansion index = 1.04.

Fig. 3. Air trapping in a bronchiole in rabbit fetus killed 15 min after delivery. An air bubble behind a pillar of unresorbed fetal pulmonary fluid $\times 145$.



air-liquid interfaces were preserved as rounded menisci. In some areas there was also evidence of air trapping in preterminal airspaces peripheral to pillars of unresorbed fetal pulmonary fluid remaining in the bronchi (Fig. 3). At later intervals there was a gradual increase in the number of air-filled alveoli but unexpanded areas still remained in animals killed 2 hours after delivery (Fig. 2c).

The morphometric analysis of the lung sections corroborated the general impression, i.e. the initial aeration of alveoli was reflected by an increasing alveolar expansion index from an average of 0.46 before the onset of breathing to 0.70 at the age of 15 min ($p < 0.001$) (Table 1). At later intervals there was a considerable variation between the individual samples, but the mean values for the alveolar expansion index remained at approximately the same level as for 15 min after delivery.

The fetus in which the roentgenologic examination had revealed transient non-aeration of the lungs had a lower alveolar expansion index (0.40) than the other animals killed at the same interval but did not otherwise deviate from the usual microscopic appearance.

The lung weight/body weight ratio was unaltered from 0 to 15 min after birth (Table 2). Thereafter the ratio gradually decreased throughout the period of observation. The difference between the groups 0 to 15 min on one hand and the groups 30 to 120 min on the other is statistically significant ($p < 0.001$).

Discussion

The results of the experiments can be condensed into three points each of which has to be considered in relation to certain observations made by previous authors.

First the aeration of the lungs of the full-term newborn rabbit appears roentgenologically to be complete within a few seconds after the onset of

Table 1

Vascular expansion index at various time intervals after delivery. The difference between animals killed in utero and those killed after 15 min is statistically highly significant ($p < 0.001$)

Postnatal age (min)	Vascular expansion index		
	Range	Mean	SD
0	0.2-0.68	0.41	0.1
1	0.41-1.09	0.9	0.4
30	0.39-0.77	0.57	0.1
60	0.40-1.01	0.60	0.14
120	0.31-1.04	0.60	0.4

Table 2

Lung weight/body weight ratio at various time intervals after delivery. The difference between the combined groups 0-15 min on one hand and the combined groups 30-120 min on the other is statistically highly significant ($p < 0.001$)

Postnatal age (min)	Lung weight/body weight (g/kg)		
	Range	Mean	SD
0	27-29	2	3
15	21-32	26	4
30	21-24	22	1
60	19-4	21	2
120	13-17	16	2

breathing. This concept is in accordance with observations made by KARLBERG (1960), FAWCETT *et al.* (1960) and LEED *et al.* (1966) who examined the lungs of fullterm newborn infants immediately after delivery using serial films as well as cineradiography. Their results suggested that the first breath of the infant leads to an overall aeration of the pulmonary parenchyma, only a slight increase in the aeration of the lungs being noted during the subsequent first few hours of postnatal life. These authors further reported that the neonatal aeration does not cause any significant change in the volume of the lungs to judge from the position of the ribs and the diaphragm before and after the first breath. In the present experiments it was not possible to identify the position of the diaphragm before the first breath and the exposures were made in antero-

posterior projection only without regard to the respiratory phase of the fetus. However, since the fetal position of the ribs was unchanged in films obtained immediately after the onset of breathing, we conclude that the first few breaths are mainly diaphragmatic. The subsequent elevation of the ribs to transverse position further suggests that there is in the newborn rabbit a transient phase of hyperexpansion of the lungs occurring within the first few minutes after birth.

Second, the distribution of air in the pulmonary parenchyma is highly irregular during the initial phase of neonatal adaptation. Many alveoli and alveolar ducts remain unexpanded during the first two hours of extra uterine life, not to be aerated until the age of 4 to 6 hours (KIMURA *et coll* 1968, GROSSMANN & ROBERTSON 1974). This irregular expansion with air trapping in preterminal airspaces is natural in a partially fluid filled parenchyma, where the distribution of air is influenced by surface forces. Later on as the fetal pulmonary fluid becomes reabsorbed and the surface forces in the alveolar lining layer are more effectively balanced by surfactant phospholipids, the expansion of the lung becomes regular and the alveoli polygonal. Our morphometric data indicate that the aeration of the parenchyma goes with a considerable increase in the relative volume of the alveolar compartment. In other words, the lungs of the rabbit fetus do not seem to be fully expanded at term (*cf* ADAMS *et coll* 1969).

Third, there is a remarkable fall in the wet weight of the rabbit lungs during the first two hours of extrauterine life. This observation agrees with the data presented by AHERNE & DAWKINS (1964). Apparently the removal of fluid from the lungs does not begin until after 15 min of age, i.e. at a stage where—according to our morphometric calculations—the postnatal expansion of the alveolar compartment has already taken place. Our morphometric calculations and lung weight recordings do not, however, permit any conclusions as to the ratio between intralveolar and interstitial pulmonary fluid. The swelling of perivascular fibrous tissue that is frequently observed in lung sections from fetuses killed during the early phase of neonatal adaptation suggests that there is an accumulation of fluid in the interstitial spaces of the lungs shortly after the onset of breathing (AHERNE & DAWKINS). In our morphometric calculations such a swelling of the interstitial tissues would cause a trend towards underestimation of the postnatal expansion of alveoli. It will to some extent mask an increase in the volume of the alveolar spaces by increasing the denominator of the alveolar expansion index.

There is a discrepancy then between the roentgenographic impression of an almost complete aeration of both lungs within a few seconds after the onset of breathing and the microscopic findings and lung weight recordings which both indicate that the aeration of the pulmonary parenchyma is protracted over a period of many hours. The roentgenologic technique used is obviously less sensitive

tive than the other two methods for determination of the fluid component of the lungs and the recognition of irregular air distribution, air trapping and foaming is limited by the maximal resolving power of the roentgen recording system. Apparently the radiologic impression of almost complete aeration can be achieved by inflation of the lungs with a volume of air which is less than the residual capacity that will normally develop during the subsequent hours of extra uterine life (cf. KARLBERG 1960).

Acknowledgement

This work was supported by the Swedish Medical Research Council (Project No. 12\ 3331) and the Swedish National Association against Heart and Chest Diseases.

SUMMARY

The lungs of fullterm newborn rabbit fetuses were examined with roentgenologic and histologic techniques. Roentgenologically there seemed to be an almost complete aeration of the lungs already within a few seconds after birth. The microscopy, however, revealed that the initial lung aeration was irregular, many alveoli containing fluid filled even after two hours of breathing. Apparently roentgenology fails to recognize the irregular aeration which characterizes the lung parenchyma in the early period of neonatal adaptation.

ZUSAMMENFASSUNG

Die Lungen ausgetragener neugeborener Fetusse des Kaninchens wurden mit roentgenologischer und histologischer Technik untersucht. Roentgenologisch scheinen die Lungen bereits innerhalb von einigen Sekunden nach der Geburt vollständig mit Luft gefüllt zu sein. Die histologische Untersuchung ergab jedoch, dass der initiale Luftgehalt der Lungen unregelmäßig war, viele Alveolen enthalten Flüssigkeit gefüllt, auch nach zweistündiger Atmung. Offensichtlich erkennen die roentgenologischen Untersuchungen den unregelmäßigen Luftgehalt festzustellen, der das Lungparenchym in der frühen Periode der neonatalen Adaptation kennzeichnet.

RÉSUMÉ

Les auteurs ont examiné par des techniques radiologiques et histologiques les poumons de fœtus de lapins nouveau-nés terme. Radiologiquement il paraît y avoir une aération effective complète des poumons dès les premières secondes après la naissance. L'examen histologique cependant a montré que l'aération initiale du poumon est irrégulière, de nombreux alvéoles restent remplies de liquide même après deux heures d'expiration. Apparemment l'examen radiologique ne permet pas de reconnaître l'aération irrégulière qui caractérise le parenchyme pulmonaire au cours de la première période d'adaptation néonatale.

REFERENCES

- ADAM F H, LATTY H, EL SALAWY A and NOZARI M The expanded lung of the term fetus *J Pediat* 75 (1969) 59
- ALPERIN W and D WARD M J R The removal of fluid from the pulmonary airways after birth in the rabbit and the effect on this of prematurity and pre natal hypoxia *Biol Neonat* 7 (1964) 214
- CALKINS H W Method for the quantitative morphologic analysis of tissues *J nat Cancer Inst* 4 (1944) 47
- E. HORNIG G, GROSSMANN G and ROBERTSON B Tracheal deposition of surfactant before the first breath *Amer Rev resp Dis* 107 (1973) 921
- and ROBERTSON B Lung expansion in the premature rabbit fetus after tracheal deposition of surfactant *Pediatrics* 50 (1972) 58
- FARWELL J, LIND J and W. GELLS C The first breath A preliminary communication describing some method of investigation of the first breath of a baby and the results obtained from them *Acta paediat* (1960) Suppl No 123 p 5
- GROSSMANN G and ROBERTSON B Lung expansion and the formation of the alveolar lining layer in the fullterm newborn rabbit Submitted for publication in *Acta paediat scand*
- KARLBERG P The adaptive changes in the immediate neonatal period with particular reference to respiration *J Pediat* 56 (1960) 585
- KADDAH Y, MOTONAGA E K and GELLS C Study of the lungs of fetal and newborn rabbits Morphologic, biochemical and surface physical development *Amer J Path* 52 (1968) 177
- LIND J, TARTI E and HERNANDEZ M Roentgenologic studies of the size of the lungs of the newborn baby before and after aeration *Ann Paediat Fenn* 12 (1966) 90

HEREDITARY HAEMORRHAGIC TELANGIECTASIA OF THE LIVER DEMONSTRATED ANGIOGRAPHICALLY

M. LEA THOMAS and HELEN CARTY

Hereditary haemorrhagic telangiectasia or Osler Weber Rendu syndrome is a familial disease characterised by telangiectasia of the mucous membranes and skin. Clinically it usually presents with recurrent or gastro-intestinal bleeding. The arteriovenous malformations may be widespread throughout the body and involve the central nervous system, the lungs, the liver and urinary tract (RENDU 1896 PARKES WEBER 1907 OSLER 1907 BURCHELL & CLAGETT 1947 SMITH & LINESBAUGH 1954 ALEXANDER & HARRINGTON 1955 MICHAELI *et coll* 1968). Rarely the arteriovenous malformations may cause enlargement of an abdominal organ.

In some organs the arteriovenous fistulae are demonstrable by angiography enabling their full extent to be more accurately defined than by clinical assessment alone.

The angiographic appearances of hereditary haemorrhagic telangiectasia of the lungs are well known (BURCHELL & CLAGETT 1949 BRINK 1950 HEDINGER *et coll* 1951 KUSHLAN 1951 ALEXANDER & HARRINGTON 1955 HODGSON

Submitted for publication 21 January 1973



FIG. 1. Microphotograph of biopsy specimen of liver showing dilatation of the sublobular portal tracts and central veins and angiomatoid nodules.

et coll 1959 MOYER et coll 1962 CHANDLER 1965). There has been a report of the lesions demonstrated by cerebral angiography (CHANDLER). The liver lesions have also been demonstrated by arteriography (RANVIGER & ÖDMAN 1963 MICHAELI et coll 1968 HALPERN et coll 1968 RAZI et coll 1971 FARRELL et coll 1972 KUNJATHWALA et coll 1972).

This paper describes the findings on hepatic angiography performed to investigate the cause of hepatomegaly in a patient with hereditary haemorrhagic telangiectasia. The differential diagnosis is discussed.

Case report

A 41-year-old woman known to have hereditary haemorrhagic telangiectasia was admitted for hepatic angiography to investigate the cause of hepatomegaly. She had telangiectasia of the lips and finger tips. Her father had malar lesions and had suffered from recurrent epistaxis.

The patient had a 10-year history of dyspepsia and a diagnosis of chronic duodenal ulcer had been made by barium meal. Four years before the angiography she had had cholecystectomy for gallstones and gastrotomy and pyloroplasty because of worsening peptic symptoms. At laparotomy the liver and spleen were slightly enlarged. The liver was finely nodular and there were dilated veins in the portal system.

A liver biopsy showed increased fibrosis around the bile ducts and in the portal tracts but there was no evidence of established cirrhosis and the parenchymal cells were normal.

Three years before the present admission she had hysterectomy for menorrhagia and test-untested liver function. Two months before the present admission she developed obstructive jaundice such as due to stones in the common bile duct. The bile duct was explored and the stones removed.

At this laparotomy the coeliac axis and its branches were observed to be greatly dilated and

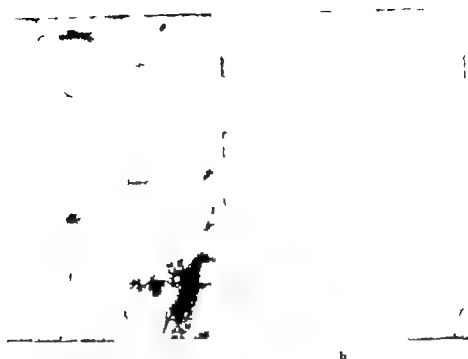


Fig. 1. Proximal aortogram. a) Arterial phase. Diameter of coeliac axis is approximately as great as that of the aorta. Early filling of hepatic cisterns (→) and contrast pooling (→). b) Hepatographic phase. Irregular nodules are contrast outlined and the normal homogeneous hepatographic appearance absent.

tortuous with palpable thrill. A liver biopsy was again taken. The histology showed dilatation of the sublobular portal tracts and central veins producing in some areas angiomatoid cystic venous dilatation. The branches of the hepatic artery were dilated. The appearances were considered typical of the telangiectatic lesions of Osler's disease (Fig. 1).

Hepatic angiography. Attempts at selective catheterization of the coeliac axis and hepatic artery proved impossible. Instead, proximal aortic injection of 80 ml. Conray 420 was made in the patient prone. A series of films of the hepatic region were taken with an AOT film hanger.

The examination showed that the coeliac axis was enormously dilated, its diameter being about as great as the aorta. The hepatic artery and its branches were also extremely dilated and tortuous, suggesting very greatly increased blood supply to the liver. The flow of the contrast medium through the hepatic artery was very fast with early filling of cisterns (Fig. 1).

In the hepatographic phase numerous diffusely scattered pools of contrast medium 1 to 2 cm in size were shown (Fig. 2 b).

Discussion

Hepatic angiography is best carried out by selective catheterisation using a preformed catheter introduced from the femoral artery. As a single hepatic artery arises from the coeliac axis in only 55 per cent of patients (STULBERG & BIERMAN 1965) satisfactory selective studies often require catheterisation of both coeliac axis and superior mesenteric artery: the otherwise underfilled areas of the liver may be confused with vascular lesions. If such selective catheterisations prove technically impossible, as in this patient, a prone flood aortogram using a large volume of contrast (80 to 100 ml) is a reliable alternative. As contrast is heavier than blood (KJELLBERG 1943) in the prone position the inferiorly placed coeliac axis and superior mesenteric arteries are preferentially demonstrated.

In the differential diagnosis of the angiographic appearances of Oler's disease of the liver the most important lesions to be excluded are primary hepatoma, hepatoma arising in a cirrhotic liver, metastases, and cavernous haemangioma, as these show increased vascularity. A primary hepatoma usually appears angiographically as a highly vascular solitary mass with small irregular areas of contrast pooling in the late phase of the examination. The main hepatic artery and its branches are usually enlarged. If the portal vein is shown to be involved by tumour the diagnosis of a hepatoma is virtually certain (BOJSEF & ABRAHAM 1965; BARTLEY *et al.* 1967; ALJIDI *et al.* 1968; FREDENS 1969; KREFL 1970).

A hepatoma in a cirrhotic liver shows similar features. However such tumours may be multiple and the parenchymal pattern of cirrhosis is present. In cirrhosis the hepatic artery and its main branches are usually of normal size but the more peripheral branches are attenuated and tortuous. In the hepatogram there is diffuse fine mottling. Rarely a large regenerating nodule may show arteriovenous shunting like a hepatoma (FARFELL *et al.*). This is however of minor degree and the bizarre irregular appearance of tumour vessels is never observed in cirrhosis alone.

Metastases also have a vascular supply but the hepatic artery is of normal calibre. Metastases often have a richer peripheral blood supply than a hepatoma giving a dense outer margin to the lesions. They are usually multiple, clearly defined, variable in size and do not show arteriovenous shunting. Normal liver parenchyma is present between them (BOJSEF & ABRAHAM).

A cavernous haemangioma characteristically has a slightly dilated hepatic artery and crowded branches. Clearly defined pools of contrast persist for a considerable time after injection (KREFL).

In hereditary haemorrhagic telangiectasia because the arteriovenous malformations are so widespread the hepatic artery and its branches may reach an

enormous size (MICHAELI et coll.) This was so in our patient (Fig 2 a) We consider this to be an important diagnostic feature as in no other condition does the arterial supply to the liver become so great Early filling of hepatic veins and venous pooling (Fig 2) are the other features of this disease (MICHAELI et coll HALPERN et coll.) The normal homogeneous pattern of the hepatogram is obscured This is replaced by ill defined nodules up to 2 cm in diameter No typical tumour circulation is seen The lesion of Osler's disease is in fact a capillary angiodysplasia

When a patient with Osler's disease develops hepatomegaly the cause may be due to either involvement of the liver by telangiectasia, cirrhosis from repeated blood transfusion given for haemorrhage or an entirely unrelated cause Thus in the management of such a patient hepatic angiography may be helpful in confirming the diagnosis of hereditary haemorrhagic telangiectasia of the liver and excluding other diseases

This report is presented to draw attention to the angiographic appearances of the liver in Osler Weber Rendu syndrome

Acknowledgements

We wish to thank Mr J M Pollan Surgeon The Royal Masonic and St Thomas's Hospitals for referring the patient for angiography We are also grateful to Dr A D Thompson Pathologist The Royal Masonic Hospital and Dr J R Tigh for the histologic reports and the macrophotograph

SUMMARY

The angiographic appearances of the liver in a patient with hereditary haemorrhagic telangiectasia are presented and the differential diagnosis discussed.

ZUSAMMENFASSUNG

Das angiographische Bild der Leber bei einer Patientin mit hereditärer hämorrhagischer Telangiectasia wird dargestellt und die Differentialdiagnose diskutiert

RÉSUMÉ

Description des aspects angiographiques du foie chez un malade atteint de telangiectasie hémorragique héréditaire et discussion du diagnostic différentiel

REFERENCES

- ALEXANDER L L and HARRINGTON L A Multiple arteriovenous fistulae of the lung N Y St J Med 55 (1955) 2807
- ALTMAN R S, RAFTOGLU H, BLOVOCORE E and BROWN C H Hepatic arteriography Radiology 90 (1968) 1136

- BARTLEY O, EDLUND Y and HELANDER C G. Angiography in primary hepatic carcinoma. *Acta radiol. Diagnosis* 6 (1967) 81.
- BOJAN E and ABRAMI H L. Roentgenologic diagnosis of primary carcinoma of the liver. *Acta radiol. Diagnosis* 3 (1963) 257.
- BRINK A J. Telangiectasias of the lungs. *Quart. J. Med.* 75 (1950) 239.
- BURCHILL H B and CLAGETT O T. Clinical syndrome associated with pulmonary arteriovenous fistula including a case report of surgical cure. *Amer. Heart J.* 34 (1947) 151.
- CHADLER D. Pulmonary and cerebral arteriovenous fistulae with Osler disease. *Arch. intern. Med.* 116 (1965) 277.
- FARRELL R, STEINMAN A and GREEN W H. Arteriovenous shunting in a regenerating liver simulating hepatoma. *Radiology* 102 (1972) 279.
- FREDEN M. Angiography in primary hepatic tumours in children. *Acta radiol. Diagnosis* 8 (1969) 193.
- HALPER M, TURNER A F and CITRON H P. An angiographic study of abdominal visceral angiodysplasias associated with gastrointestinal haemorrhage. *Radiology* 90 (1968) 1143.
- HEDINGER C, HIRTZ W H and MARNIER C. Arteriovenous pulmonary aneurysms: relation to Osler's disease. *Schweiz. med. Wochschr.* 81 (1951) 367.
- HODGSON C H, BURCHILL H B, GOOD C A and CLAGETT O T. Hereditary haemorrhagic telangiectasias and pulmonary arteriovenous fistula—survey of a large family. *New Engl. J. Med.* 261 (1959) 625.
- KJELLSEK R. Die Mischungs- und Stromungsverhältnisse von wasserlöslichen Kontrastmitteln bei Gefäß- und Harnuntersuchungen. *Acta radiol.* 24 (1943) 433.
- KJERFASW LA N N, BECKER J A and RABINOWITZ J G. Osler Weber Rendu syndrome: the multiple angiographic findings. *Brit. J. Radiol.* 45 (1972) 534.
- KREEL L. Vascular radiology in liver disease. *Postgrad. med. J.* 46 (1970) 19.
- KUSILAN S D. Hereditary haemorrhagic telangiectasia with pulmonary arteriovenous aneurysm: possible etiology and prophylaxis. *Conn. med. J.* 15 (1911) 505.
- MICHAELI D, BEN BASAT I, MILLER H J and DEUTSCH V. Hepatic telangiectasias and portosystemic encephalopathy in Osler Weber Rendu disease. *Gastroenterology* 54 (1968) 929.
- MOYER J H, GLANTZ G and BREIT A. Pulmonary arteriovenous fistula. *Amer. J. Med.* 32 (1962) 417.
- OSLER W. On family form of recurring epistaxis associated multiple telangiectasias of the skin and mucous membranes. *Bull. Johns Hopk. Hosp.* 12 (1907) 303.
- LARSEN WEST F. Multiple hereditary developmental angiomata (telangiectasias) of the skin and mucous membranes associated with recurring haemorrhages. *Lancet* 2 (1907) 160.
- VON RANCIER J and ODON I. Angiographischer Nachweis multipler arteriovenöser Anastomosen in der Leber bei einem Patienten mit familiärer Telangiectasia. *Fortschr. Röntgenstr.* 98 (1963) 768.
- RAJCA A. Hemangiomas and arteriovenous aneurysm of the lung. *Presse méd.* 111 (1919) 776.
- RAX H, BYLLER B M, GINDONI J, LINHART J W, TALLEY R C and URRAN F. Hyperdynamic regulatory state due to intrahepatic fistula in Osler Weber Rendu disease. *Amer. J. Med.* 50 (1971) 809.
- REY H. Epistaxis répétées chez un sujet porteur des petites angiomes cutanés et muqueux. *Bull. Soc. Méd. Paris* 13 (1896) 731.
- SMITH J L and LIN RACK M J. Hereditary haemorrhagic telangiectasia. *Amer. J. Med.* 17 (1954) 41.
- STILBERG H J and BURMAN H R. Selective hepatic arteriography. *Radiology* 85 (1965) 46.

SOFT TISSUE RADIOGRAPHY OF FINGER JOINTS

S. REICHMANN, E. DEICHOWABER, K. G. STRID, F. HEYMAN and T. STRAND

Soft tissue changes constitute a prominent feature in rheumatoid arthritis giving rise to the typical spindle-shaped appearance of the fingers involved (RAGAN 1967). Periarthritic swelling has been reported to be the earliest roentgen sign in this region (SÖRTH 1967) although it has apparently been observed in standard as opposed to special soft tissue films. The present communication deals with the finger joint appearances when examined with a technique similar to that used in the examination of the female breast. A description of the roentgen appearances of the normal and arthritic conditions will be supplemented by certain aspects of the technique.

Material and Methods The material consisted of three groups. The first of these comprised 20 women with rheumatoid arthritis and aged between 19 and 74 years. In 11 of these the diagnosis was confirmed by serologic tests whereas in the remainder the serology was unknown. The clinical and roentgenographic appearance indicated rheumatoid arthritis. The disease was more or less advanced but without crippling deformities or generalized ankylosis. Considerable



Fig. 1 Metacarpophalangeal joints of left hand: a) Control b) Female with rheumatoid arthritis. The \square is the right extreme in both films: wedge-shaped pad of fat between the joints in (a) partially blurred in (b) owing to soft tissue swelling around the joints of digits 2 and 3. No swelling around the joint of digit 4. Sharp boundary of soft tissue swelling at the distal aspect of the digit 2 joint (\rightarrow).

differences existed within the group as regards the degree of rheumatic activity: all patients in this group had been treated for a considerable time. The second group consisted of 11 patients: 6 males and 5 females aged between 18 and 62 years suffering from miscellaneous conditions, some with Heberden's nodes and others with early arthritis of uncertain type. The third group was made up of 15 control patients: 7 females and 8 males aged between 19 and 74 years. None of them displayed any symptoms or signs of disease of the finger joints.

The technique was not uniform in that the experiences as gained were immediately converted into improvements. Certain aspects of the choice of roentgen tube, of the projections, and of the positioning of the patients will consequently be presented as part of the results.

All recordings were made on industrial non-screen film Agfa/Gevaert Mamoray 2 developed in a roll machine in 6 min (DISCHINGER *et coll.* 1974); developer Agfa/Gevaert G 122; fixer Agfa/Gevaert G 322. Two types of roentgen apparatus were used: one was a Siemens Mammomat equipped with a molybdenum target roentgen tube and a molybdenum filter as described by Gross (1967); tube potential 35 kV. The second apparatus consisted of a kVd board fitted with a tungsten rhenium target roentgen tube with a tube window of an absorption equivalent to that of 0.5 mm Al; no additional filtration was used. A x-ray generator was used at a tube potential of 26 kV, this value being ascertained by direct measurements. Higher potentials—up to 40 kV—were employed only occasionally.



Fig 2 a) Joints of the thumb in control case b) 1st metacarpophalangeal joint of a female with rheumatoid arthritis. Soft tissue swelling on lateral aspect of joint

b

The projections consisted of one perpendicular to the hand and one or two oblique projections. The lateral projection was discarded after preliminary testing owing to the length of exposure time. The roentgenograms of the control group were inspected first, after which the different types of soft tissue changes and skeletal changes were tabulated for all finger joints of the subjects with disease. As the technique was altered during the investigation the frequency of the different changes will not be mentioned; this scrutiny merely served the purpose of making the authors familiar with the possible variations. Only one factor will be discussed: the degree of correlation between skeletal and soft tissue changes.

No attempts were made to correlate the radiographic findings with the clinical state of the patients.

The roentgen exposure and the spectral distribution of the radiation were determined for the method considered best from a clinical point of view. The exposure rate at a given point in the roentgen radiation field may be expressed

$$I = \frac{I_0}{r^2}$$

where I is the total relative intensity calculated from the mathematic model (STRO 1972; STRO & LANTZ 1973); I_0 the roentgen tube current; r the distance from the tube focus to the point; and α a universal constant. The exposure measurements (LANTZ & STRO 1973) indicated that $\alpha \approx 0.10 \text{ mR m}^2 \text{ mA}^{-1}$. Most of the roentgenograms were obtained with a tungsten tube operating at 26 kV, the target-object distance being 66 cm at 130 mAs. For 26 kV tungsten

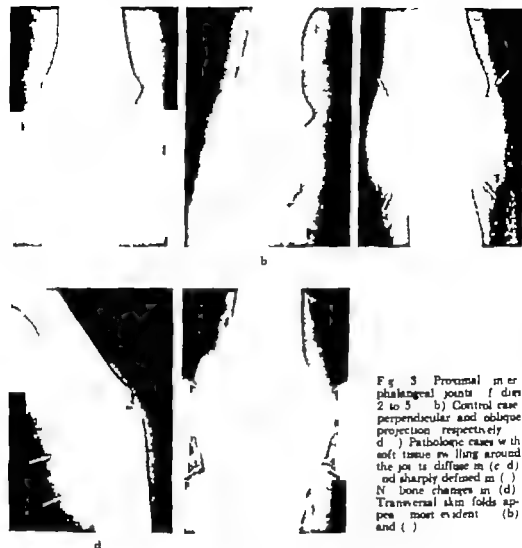


Fig. 3. Proximal interphalangeal joints of fingers 2 to 5. a) Control case perpendicular and oblique projection respectively. b) Pathologic cases with soft tissue swelling around the joint is diffuse in (c, d) and sharply defined in (e). No bone changes in (d). Transversal skin folds appear most evident in (b) and (e).

radiation filtered through 0.5 mm aluminium and 66 cm air I was calculated to be 15.9; the object was thus exposed to c. 0.47 R for each roentgenogram.

Results

The metacarpophalangeal joints of the 2nd to 5th fingers are surrounded by the interosseous and lumbrical muscles between the heads of which usually lies a wedge shaped pad of fat tissue (Fig. 1 a). The presence of muscle tissue

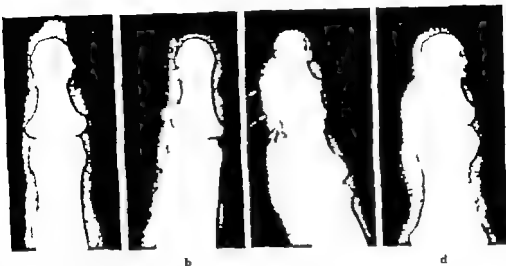


Fig. 4 Distal interphalangeal joints of digits 2 to 5 (a and b) The normal joint appearances in different projections (c and d) Diffuse soft tissue swellings but no skeletal changes in (d)

often masked the joints in the early stages of a disease so as to raise doubt as to whether a soft tissue swelling existed or not. This obstacle was however largely overcome in muscular atrophy (Fig. 1 b). Atrophy was discernible as a general reduction in the roentgen absorption in conjunction with infiltration of fat in the muscles; the fat pads also grew broader in muscular atrophy so that the periarticular reactions were more easily demonstrable in patients who had been suffering from arthritis for some years. The contribution of a soft tissue technique to the early diagnosis of arthritis in the joints thus appears to be limited although as will be discussed later reason seems to exist to expect that this technique even in chronic cases may prove valuable.

The soft tissue changes in the metacarpophalangeal joints other than those of the thumb mainly consisted of diffuse oedematous infiltration (Fig. 1 b). Only rarely were such sharply limited areas of infiltration as will be described below for other joints evident (Fig. 1 b). The metacarpophalangeal joint of the thumb is largely covered by the thenar muscles. The capsule on the dorsal aspect of the joint lies however close to the subcutis (Fig. 2 a) which makes its examination easier. Periarticular oedema was again a prominent feature (Fig. 2 b).

The interphalangeal joints of the 2nd to 5th fingers seemed to lend themselves to accurate soft tissue examination. A thin stripe of fat tissue was normally evident on each side of the joint (Fig. 3 a, b) while proximally and distally to



Fig. 5. Proximal interphalangeal joints of digit 3 (to the right) and 4 in advanced rheumatoid arthritis. Joint surfaces totally destroyed in both joints; soft tissue reaction in digit 3 but not in digit 4.

the joint these stripes usually widened. The skin folds on the dorsal aspect of the joints often resembled an articular swelling. Two main abnormalities were recorded. One—the more common—was diffuse periarticular oedema (Fig. 3 c); this was easily detectable, giving the impression that early and accurate diagnosis of arthritis might be possible. In fact, two patients in the miscellaneous group displayed such soft tissue swelling without any skeletal changes (Fig. 3 d). The second roentgen sign of joint abnormality consisted of a sharply demarcated area of increased periarticular roentgen absorption (Fig. 3 e). Whether this was also due to oedema or if some other abnormality such as periarticular fibrosis was present was not obvious.

The distal joints of the 2nd to 5th fingers were generally not surrounded by the same amounts of fat tissue as the proximal joints of the same fingers. This was specially so in the projection perpendicular to the hand (Fig. 4 a) while the oblique projections disclosed more of the borders of the joint capsule (Fig. 4 b). It was consequently somewhat more difficult to demonstrate the existence of minor degrees of oedematous infiltration. Fig. 4 c and d illustrates two distal joints with marked periarticular oedema. One of these was of a woman with a seropositive rheumatoid arthritis; the other a woman with arthritis of unknown aetiology but no skeletal changes. Increased roentgen absorption of the soft tissues around the joints with advanced changes of the Heberdeen type was also present.

The projections used presented the interphalangeal joint of the thumb more or less from the side (Fig. 2 a); this did not interfere with the interpretation, however, as the images were similar to those of other finger joints with arthritis.

One striking feature was the absence of correlation between the soft tissue and skeletal changes. Joints without the latter might display obvious soft tissue

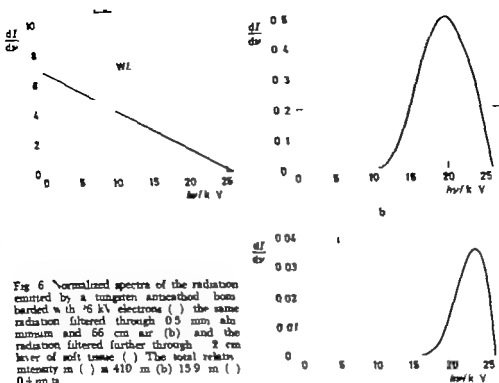


Fig. 6 Normalized spectra of the radiation emitted by a tungsten anticathode bombarded with 26 kV electrons () the same radiation filtered through 0.5 mm aluminium and 66 cm air (b) and the radiation filtered further through 2 cm layer of soft tissue () The total relative intensity in () is 410 in (b) 159 in () 0 + cm air

cases of disease (Fig. 3 d + 4 d). On the other hand those with advanced destruction might be combined with any degree of soft tissue changes (Fig. 5).

Both types of roentgen apparatus produced acceptable roentgenograms although the skull board with the tungsten target tube was preferred for several reasons. The fact that the molybdenum tube gave inconveniently high contrast tended to underexpose thick fingers and overexpose slender fingers; moreover the skeleton was sometimes difficult to define making special skeletal films necessary. All these disadvantages were acceptably eliminated with the tungsten tube operating at 26 kV while the reduction in contrast failed significantly to impair the examination of the soft tissues. The impression was gained that the potential of a tungsten tube should not be allowed to rise much above 26 kV since the perception of fine soft tissue detail is then rendered increasingly difficult. The first cases were examined at 40 kV, a potential that was subsequently regarded as completely unsuitable. Only a vague outline of the joint capsules could then be perceived (Fig. 3 d). The conclusion was thus drawn that although

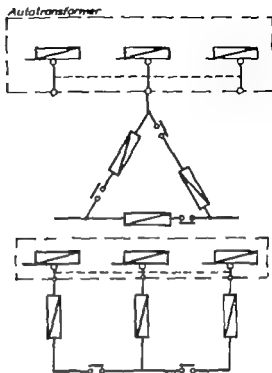


Fig. 7. Wiring diagram of sample means of modifying standard delta connected generator (top) into a star connected generator (bottom) reducing the tube potential by a factor of $\sqrt{3}$. 40 kV with this connected transformer is reduced to 23 kV.

a tungsten target seems preferable to a molybdenum one. A special tube with low inherent filtration is still needed for use at the lower potentials. Standard roentgen tubes and unadapted generators seem to be unsatisfactory for the present purpose.

Three projections proved to be preferable: one perpendicular to the hand and two oblique. It was apparent again and again that the demonstration of only slight particular changes indicated simultaneous scrutiny of all three projections. The accomplishment of the oblique projections turned out to be problematic, however. The roentgen beam could with the Mammomat not be angled and the hand had to be turned instead. The rheumatic condition of the patients in combination with long exposure times produced however disturbing movement unsharpness more often than was acceptable as most fingers had to be left without support. Stabilizing devices invariably appeared in the roentgenograms and impaired the image quality. The skull board enabled the problem to be solved by angling the beam 30° to either side without moving the film or the hand that rested upon it. This procedure gave rise to lateral distortion which although it failed to disturb interpretation also produced an increase in geometric un-

sharpness thus becoming barely tolerable. The FFD was 68 cm and the focus size for the actual tube load $0.7 \text{ mm} \times 1.0 \text{ mm}$. The focus measurement was made according to the DIN procedure except for the tube load. Angulation of the tube in the direction of the smallest focal dimension proved to be preferable. Since the smallest dimension of a focus is generally directed at right angles to the longitudinal axis of the tube, the latter should be angled in a direction perpendicular to its long axis and not in the direction of the axis as is usual in most installations.

The roentgen spectrum was calculated by a mathematic model (Ström 1972, Ström & Lantz 1973). The radiation reaching the object from a tungsten target bombarded with 26 kV electrons consists mainly of photons with energy in the range 15 to 25 keV (Fig. 6). A soft tissue layer 2 cm thick absorbs 97.5 per cent of the radiation energy entering it. The linear extinction coefficient of soft tissue was calculated to be 1.0 cm^{-1} for 25 keV photons and $c. 5 \times 10^{-1} \text{ cm}^{-1}$ for photons of $c. 0.5 \text{ keV}$. Thus from the physical point of view the contrast due to variations in the soft tissue attenuation is far from optimal with 26 kV radiation. Clinical experience however indicates that increased physical contrast does not necessarily imply improved visibility.

Discussion

Soft tissue examinations of the finger joints require special equipment. Experiences suggest that the skull board or any similar apparatus with which the roentgen beam may be conveniently angled is best. The tube should have a tungsten target, a low degree of inherent filtration and a potential of about 26 kV. Most clinics possess a skull board or a similar device but the tube and the generator are usually unsuitable for soft tissue. The suggestion is made that next time the tube is changed one of low inherent filtration such as Siemens Bz 125/30/50 MaR be installed. All types of conventional radiography may with additional filtration be performed with such a tube. The problem of the generator remains. The present authors modified a standard transformer so that it could be used for conventional potentials (40 to 120 kV) as well as for lower voltages (23 to 40 kV). A wiring diagram of the modified generator—a Triplex Optimatic 1023 m from Elema Schonander—appears in Fig. 7. It is suggested that if a skull table is to be adapted to soft tissue radiography the manufacturers of the equipment should be asked whether it is possible to modify the generator at the same time.

The present report indicates that soft tissue roentgenography may contribute to the clinical handling of conditions of the finger joint. Two aspects seem to merit further attention. One is the question whether this can provide earlier

diagnosis of arthritis than is possible today. The other is the problem whether there is justification for assuming that the state of the soft tissues directly reflects the activity of the disease, regardless of the degree of skeletal changes. These problems require further investigation.

SUMMARY

Finger joints have been examined roentgenologically with a soft tissue technique at a relatively low kilovoltage. Particular attention has been directed to modification of the equipment. Soft tissue films appear to enhance the value of the examination of these joints and to supplement the routine roentgenograms of the bones.

ZUSAMMENFASSUNG

Fingergelenke wurden roentgenologisch mit einer Weichgewebetechnik bei einem relativ niedrigen Kilovoltwert untersucht. Besonderer Wert wurde auf eine Abänderung der Ausrüstung gelegt. Weichgewebe Filme scheinen den Wert der Untersuchung dieser Gelenke zu erhöhen und die Ergebnisse der Routineroentgenbilder der Knochen zu ergänzen.

RÉSUMÉ

Les articulations digitales ont été examinées radiographiquement par une technique de parties molles avec un kilovoltage relativement bas. Les auteurs se sont attachés particulièrement à la modification de l'équipement. Les films pour tissus mous paraissent augmenter la valeur de l'examen de ces articulations et compléter les radiographies ordinaires du squelette.

REFERENCES

- DEICHGRAEFER E., REICHMANN S. and BUREN M.: Film quality in mammary radiography. *Acta radiol. Diagnosis* 15 (1974) 93.
- GROS C. M.: Méthodologie. Symposium Européen de Radiologie Mammaire. *J. Radiol. Électrol.* 48 (1967) 638.
- LANTZ B. and STRID H. G.: Contrast formation in fluoroscopic ideodensitometry. II. A comparison between theoretically computed and experimentally measured contrast. *Acta radiol. Diagnosis* 14 (1973) 625.
- RAGAN C. H.: The clinical picture of rheumatoid arthritis. In: *Arthritis and allied conditions*, p. 211. Ed. ted by J. L. Hollander. Lea & Febiger, Philadelphia 1967.
- SWYTH C. H.: Radiology in rheumatic diseases. In: *Arthritis and allied conditions*, p. 130. Ed. ted by J. L. Hollander. Lea & Febiger, Philadelphia 1967.
- STRID H. G.: Optimisation of contrast in radiography. Gothenburg Inst. Phys. Rep. GIPR-001 (1972).
- STRID H. G. and LANTZ B.: Contrast formation in fluoroscopic ideodensitometry. I. A mathematical model for optimising contrast in radiography. *Acta radiol. Diagnosis* 14 (1973) 393.

HOMOGENEITY OF INTENSIFYING SCREENS

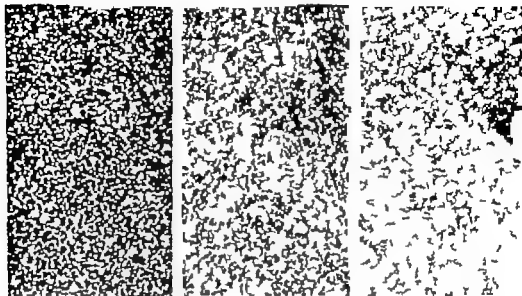
S. REICHMANN and C. G. HELANDER

The quality of the screen film combination greatly influences the total noise level of a radiographic system. First of all the sensitivity determines the roentgen dose and thus also the quantum mottle, so that high sensitivity makes for high quantum mottle. This is universally recognized. However little information has been published as to whether the crystal structure of the screens introduces structure mottle to such a degree as to be harmful in everyday routine work. CLARE et coll (1962) stated from experiments that this was not so. REICHMANN (1974) in comparing two different screen film combinations observed that a considerable difference in noise could be discerned despite the fact that the combinations tested were of identical sensitivity. The question thus arises whether the differences were due to variations in the homogeneity of the roentgen absorption of the screens. Since CLARE et coll tested only one commercially available calcium tungstate screen—without mentioning the exact make—together with one specially made potassium iodide screen there appeared to be justification to revert to the problem somewhat more thoroughly.

The influence of screen structure on image quality was investigated in two experiments: one based upon the other.

The first goal was to find out whether the absorption of commercially available screens was homogeneous or varied overall. The following front screens were

Submitted for publication 20 June 1973



b

Fig. 1. Roentgenograms of intensifying screens. Dark areas in the image correspond to low roentgen absorption in the screen. The structure is: a) coarse, b) intermediate, and c) fine; the screens belonging to categories I, II, and III, respectively. Magnification $\times 6$. The contrast has to the same degree been enhanced.

tested by radiography: Siemens Saphir, Siemens Rubin, Cawo Universal, Cawofin, Philips Universal, Du Pont Par Speed, Kodak X-omatic Regular, and Kodak X-omatic Fine. The screen to be examined was placed upside down on a double-wrapped industrial roentgen film (Agfa/Gevaert Mamoray T3); the film was thus blackened not by the light emitted by the screen but by the roentgen rays passing through it. Tube potential was 23 kV, tungsten anode. The resulting roentgenograms displayed inhomogeneous blackening owing to the crystal structure of the screens. The mottle thus recorded suggested that the screens could be divided into three groups (Fig. 1). The first of these had the most obvious mottle. The following screens belonged to this category: Siemens Saphir, Siemens Rubin, Cawo Universal, Cawofin, and Philips Universal. The Du Pont Par Speed screen constituted the second group with a somewhat lower mottle. The Kodak X-omatic screens—forming the third group—turned out to have remarkably low mottle (Fig. 1c); no clear difference was evident between the two screens in this group.

Types of experiments mentioned by CLIFARE et al. were next used to determine how much the inhomogeneities influenced the final noise level. The screens

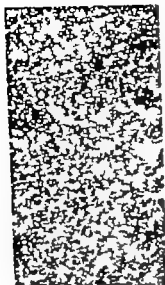


Fig. 2 Roentgen image formed with screen belonging to category I (coarse crystal structure) the same as in Fig. 1 a). The coarse inhomogeneities of the blackening constitute the mottle; the structure mottle predominated over the quantum mottle. Magnification $\times 6$. The contrast has been enhanced.

were permanently glued into cassettes onto the front of which roentgen absorbing markers were fastened. After development a film exposed within a cassette displayed an image of the markers against a grey background containing various noise levels. Two exposures were made on every type of film for every screen with a tube potential of 60 kV. The films were developed in a 90 second roll machine. The following types were used: Kodak RP/R, Agfa/Gevaert Curix RP, Kodak X-omatic General and Kodak Kodath Ortho type III. The last mentioned film is a photo-technical one of low sensitivity; the others are conventional radiographic films. Between these roentgen films the sensitivity factor is 2 so that RP/R is about 4 times faster than X-omatic General. After development the two films of each type were superimposed—a procedure guided by the markers—and the mottle examined. If the pattern was identical in the two images so that they completely covered each other it was concluded that it was formed by structure mottle rather than pure quantum mottle. It was doubtful in one instance whether the mottle pattern of the two films really was identical—a subtraction image had to be made from the two films so that the structure mottle was eliminated.

The following results were obtained. Screens belonging to category I—having the coarsest structure—gave rise to structure mottle in all films (Fig. 2). This mottle seemed to predominate over the quantum mottle. The predominance was less marked with the film of the highest sensitivity. The mottle had the same appearance as the one in the roentgenograms of the screens (Fig. 2). In a screen

category II—Du Pont Par Speed—structure mottle was visible in films of low sensitivity with high sensitivity the quantum mottle predominated. In category III—the Kodak X-omatic screens—no structure mottle could be detected in any film.

Discussion

The structure of intensifying screens is of greater significance than seems to have been hitherto believed. The clinical comparison by REICHMANN between a screen of category I (coarse structure) and one of category III (fine structure) clearly demonstrated that the noise level in the former can be so high as seriously to impair the depiction of faint but clinically important signals. REICHMANN assumed that the X-omatic screens must have an improved capacity to absorb roentgen photons. Such an assumption might suggest that the thickness of the absorbing layer must be extraordinary high. The present investigation indicates however that the improvement is due to increased homogeneity of absorption, so that no roentgen photon can escape between the crystals of the fluorescent layer.

The lower noise level of screens belonging to category III seems in fact to be a prerequisite for better image quality in some types of examination.

An exceptionally low noise level is mandatory in specialized soft tissue radiography such as mammary radiography (DEICHOEABER *et coll.* 1974). For this reason many prefer non screen industrial roentgen film for such examinations (EGAN 1964; GERSHON COHEN *et coll.* 1970; DEICHOEABER *et coll.* 1974). A screen technique has been attempted (PRICE & BUTLER 1970) but the resulting change in noise level was not thoroughly examined. The high roentgen doses in these types of examination make it desirable that a screen technique will be developed to improve the absorption capacity of the recording medium. Screens with a fine structure should be combined with a film of low or moderate sensitivity. In this way both structure mottle and quantum mottle will be kept low. It may be pointed out in this connection that the grain of the film also constitutes a kind of noise that cannot be ignored. This problem will be treated in a later publication.

About a decade ago high voltage technique utilising potentials up to 200 kV was tested. It seems now to have been abandoned however the general reason for this being the low contrast. This means that so many signals were brought under the noise level of the roentgen system that the images were regarded as unacceptable. However the introduction of screens with a low structure mottle may offer new possibilities in high potential radiography. The hypothesis is that fine-structure screens are combined with a suitable film so as to give an optimal

structure mottle, quantum mottle and film grain mottle the lowered signal intensity in high potential radiography is then compensated for by a lowering of the noise level so that the signal/noise ratio remains unchanged

SUMMARY

The crystal structure of intensifying screens has been investigated. A coarse structure will impair the image quality owing to increased noise termed structure mottle. Screens of very fine structure have recently been introduced. Some new applications for such screens are discussed.

ZUSAMMENFASSUNG

Die Kristallstruktur von Verstärkschirmen wurde untersucht. Eine grobe Struktur erschlechtert die Bildqualität infolge des erhöhten Rauschens. Struktur-Fleckigkeit benannt. Schirme mit sehr feiner Struktur sind kürzlich introduziert worden. Einige neue Anwendungen für diese Schirme werden diskutiert.

RÉSUMÉ

Les auteurs ont étudié la structure cristalline des écrans renforceurs. Une structure grossière diminue la qualité de l'image du fait de l'augmentation du bruit de fond appelée granularité structurale. Des écrans à structure très fine ont été récemment introduits. Les auteurs examinent quelques nouvelles applications de ces écrans.

REFERENCES

- CLEARE H. M., SPLETSTONER H. R. and SEIDMAN H. E. An experimental study of the mottle produced by X-ray intensifying screens. *Amer. J. Roentgenol.* 88 (1962) 168.
 DESCHERLAKER E., REICHMANN S. and BURDET M. Film quality in mammary radiography. *Acta radiol. Diagnosis* 15 (1974) 93.
 EGAN R. L. *Mammography*. Charles C. Thomas, Springfield, Illinois, 1964.
 GIBSON CONYER J., HERMEL M. B. and BARNER J. W. Advances in mammographic technique. *Amer. J. Roentgenol.* 108 (1970) 424.
 FRICK J. L. and BUTLER P. D. The reduction of radiation and exposure time in mammography. *Brit. J. Radiol.* 43 (1970) 251.
 REICHMANN S. Efficiency of intensifying screens. *Acta radiol. Diagnosis* 15 (1974) 293.

ABSORBED GONAD AND INTEGRAL DOSES TO THE PATIENT AND PERSONNEL FROM ANGIOGRAPHIC PROCEDURES

J HAUGE and G SVÄHN

Two reasons in particular initiated the present investigation. The steadily increasing number of angiographic examinations (STRIKZ 1969) and our relative lack of knowledge of doses delivered to the patient and personnel from angiographic procedures. In Sweden measurements of gonad and integral doses to the patient have been reported in only a few angiographic examinations (LARSSON 1958 CARLSSON 1963). Other measurements, some of which include doses to the personnel, are limited to cardiac examination (GOUTH et coll 1968 ARDRAN et coll 1970 1973 HAWKINS et coll 1970 MALSBY et coll 1971 WOLD et coll 1971) or to cerebral angiography (BERGSTROM et coll 1972).

Diagnostic equipment and technique Cardioangiography was performed with Siemens biplane equipment: two 23/15 cm image intensifiers with automatic brightness control for fluoroscopy (exposure rate 20 respectively 40 / R/s on the

The article is based on a paper presented at the 31 Congress of Nordic Society for Medical Radiology, Reykjavik, June 1971. Submitted for publication 3 May 1973.

Table 1

Gonad and integral doses from abdominal angiography in adults (gonads not shielded)

	No of measurements	Gonad dose mrad		Integral dose (kg rad)	
		Range	Mean	Range	Mean
Fluoroscopy	8	< 2-110	31	1-92	53
Serial radiography	8	80-110	114	57-443	140
Total dose	16	7-470	143	87-533	173

8 measurements

input screen) 70 mm cameras for serial fluorography (film rate up to 6 frames/s automatically controlled exposure 100 μ R/frame on the input screen) 35 mm cine cameras, usually operated at 75 frames/s (exposure 20 μ R/frame) Serial radiography was performed with Elena Schonander 35 cm \times 35 cm cut film changers at a rate of up to 6 films/s (exposure to the film 1.2 mR not automatically controlled)

The focal spot size was as follows: overhead tube for fluoroscopy and filming 0.6/1.0 mm overhead stereo tube (used in most abdominal angiographies) 1.0 mm and the tube in horizontal beam 0.3/1.3 mm The overhead fluoroscopy tube was shielded with lead rubber drapes

The total time for fluoroscopy in abdominal angiography varied between 3 and 57 min (mean 29 min) In cardiac examinations of adults the fluoroscopy time was between 5 and 43 min (mean 19 min) and in children between 3 and 39 min (mean 16 min) The total time for biplane cinefluorography varied between 13 and 40 s Fifty to 315 70 mm fluorograms and 17 to 94 full size films were exposed per examination

In abdominal angiography the 30 cm \times 30 cm field size with stereo tube was used at least in one series Otherwise at filming and at fluoroscopy the primary diaphragms were carefully collimated

The film material used was as follows: Gevapan 36/19² for 35 mm cinefluorography Gevaert Scovax HD for 70 mm fluorography and DuPont D4 or CEA film with Siemens Special intensifying screens for serial radiography The films—with exception for obese patients—were obtained at 90 kV p or lower

Material and method of measurements Gonad or integral doses to the patient were measured in 60 examinations—16 abdominal and 12 cardioangiographies in adults and in 32 cardioangiographies in children (age 15 years or less) Abdominal angiographies in children were not performed during the period

Table 2

Gonad and integral doses from bi plane cardioangiography in adults

	N of measurements	Gonad dose (mrad)				No of measurements	Integral dose (kg rad)	
		Gonads shielded		Gonads not shielded			Range	Mean
		Range	Mean	Range	Mean			
Fluoroscopy	5	< 2		< 2-15	7	10	1-31	13
3 mm cine	4	< 2	2.0	2-10	6	8	7-43	22
70-mm fluorography	3	< 2		< 2-5	2	6	1-11	8
Serial radiography	4	< 2-7	2.0	4-100	27	8	4-45	11
Total dose*	5	< 2-7	4	6-108	42	10	17-101	58

* Not all methods of filming used in every patient

Table 3

Gonad and integral doses from bi plane cardioangiography in children (0-15 years)

	N of measurements	Gonad dose (mrad)				Integral dose (kg rad)	
		Gonads shielded		Gonads not shielded			
		Range	Mean	Range	Mean	Range	Mean
Fluoroscopy	14	< 2-15	5.5			0.5-12	3
16 mm cine	8	< 2-8	4	Not separately determined		0.5-23	8
Serial radiography	9	2-9	5			3.5-11	7
Total dose	12	3-27	13	12-900	280	1-47	16

* In measurements

† In some patients only one method of filming used

At 47 examinations, doses to the personnel (radiologist, radiology technician, cardiologist and pediatric nurse) were determined.

Absorbed and gonad doses were measured with calibrated LiF thermoluminescent dosimeters. Error in measurements was not more than 10 per cent with increasing accuracy for higher doses, and the lowest measurable dose was less than 2 mrad.

For measurements of gonad dose in male patients, the dosimeters were placed on the testicles. In females the doses in ovary region with dosimeters in the rectum were not measured as it was difficult to change them during the examination under sterile conditions. In a number of cases the gonads of the patients were shielded by a 2 mm thick lead rubber.

Absorbed doses to the personnel were measured with dosimeters on the third finger of both hands, on the forehead and in the gonad region underneath the lead rubber apron (lead equivalent 0.5 mm).

During the filming, the radiologist, the technician and the cardiologist attending at heart catheterization left the examination room (exception coronary and small vessel angiography requiring manual injection by the radiologist). The pediatric nurse eventually holding the child stayed in the room as all examinations were performed without general anesthesia.

Areal exposure ($R \times cm$) was measured with light transparent, plane parallel ionization chambers (Pychlau Freiburg/Baden). The values were registered with an electrometer recorded graphically and integral doses in kg rad were calculated from the records (CARLSSON 1963, 1964).

Results

The patient. The highest gonad (mean 145 mrad) and integral doses (mean 175 kg rad) were delivered by abdominal angiography (Table 1). Of the total gonad dose as well as of the total integral dose approximately 20 per cent were contributed by fluoroscopy and 80 per cent by serial radiography. In cardioangiography of adults 70 mm fluorography delivered lower gonad and integral doses than both serial radiography and 35 mm cinefluorography and contributed to the total dose even less than fluoroscopy. Lead rubber shields reduced the gonad dose to approximately 10 per cent of that without protection (Table 2).

In cardioangiography of children approximately the same integral dose was contributed from both serial radiography and 35 mm cinefluorography. 70 mm fluorography was not used in children. The gonad dose with gonads shielded was approximately 5 per cent of that without protection (Table 3).

Table 4

Absorbed doses to the personnel from angiographic procedures (mrad)

Radiologist						Eyes	Gonads
No of measure- ments		Middle finger					
		Right		Left			
		Range	Mean	Range	Mean		
Abdominal angio- graphy	8	< 2-33	11	< 2-112	26	Not mea- surable	Not mea- surable
Cardio- angio- graphy (adults)	10	< 2-31	9	< 2-41	11		
Cardio angio- graphy (children)	29	< 2-110	13	< 2-90	15		
12 measurements						(< 2)	(< 2)

The personnel The mean absorbed dose to the middle finger of the radiologist varied depending on the type of examination between 9 and 26 mrad. The highest dose—112 mrad to the left hand—was measured during abdominal angiography (Table 4).

The absorbed doses to the fingers of the pediatric nurse varied even to a greater extent depending on if the child had to be held during the examination or not. The lowest absorbed dose was less than 2 mrad, the highest 760 mrad, probably caused by direct irradiation of the fingers holding an infant during fluoroscopy and filming. The mean absorbed dose to the right middle finger of the pediatric nurse was 75 mrad and to her left middle finger 89 mrad. The mean absorbed dose to the eyes was 5 mrad per examination.

The absorbed doses to the eyes of the radiologist, to the fingers or the eyes of the cardiologist and radiology technician—both at a greater distance from the roentgen tube—as well as gonad doses to any of the attending personnel were not measurable i.e. they were less than 2 mrad per examination.

Tabl 4 (cont.)

Pediatric name						
No. of measure- ments	Middle finger		Eyes		Gon- ads	
	Right		Left		Range	
	Range	Mean	Range	Mean	Range	Mean
	< 2-40	7	< 2-760	89	< 2-11	5

Discussion

The patient In cardioangiography of children without gonad protection the absorbed dose to the gonads was high because of the short field gonad distance. The exceptionally high dose in one case (900 mrad) indicates direct irradiation of gonads probably during fluoroscopy at catheterization. In adults the mean gonad dose without gonad shield (42 mrad) was higher than the 25 mrad reported by Gouvis et coll (1968) one of the reasons probably being that we used biplane cinefluorography and a higher frame rate.

With the use of 70 mm fluorography in cardioangiography of the adults gonads not shielded the mean gonad dose was reduced to approximately 8 per cent of that in serial radiography. The lowest gonad dose was found when gonads were shielded and recording systems from the output screen of the image intensifier were used. The marked reduction of the gonad dose in both children and adults by shielding stresses the effectiveness of this simple protective measure. It should be used in all examinations of children and of adults in fertile age including abdominal angiography if the shields do not interfere with the examination.

The integral doses were highest in abdominal angiography. They varied largely with the exposure rate, time of fluoroscopy, number of films and mainly with the field size. In some cases, selective catheterization of sclerotic visceral arteries prolonged markedly the fluoroscopy time. In fluoroscopy of the abdomen, the use of improved image intensifiers with automatic exposure control reduced the integral dose rate from 1.1 kg rad/min (LAUDE 1968) to 0.7 kg rad/min. However, the image intensifier television systems with automatic brightness control must be continuously tested for their function, and the radiologist must be aware of the potential dangers of increasing the exposure and dose rates with these units (STIEVE 1969).

Since our preliminary report on dose measurements in angiography (LAUDE *et coll.* 1972) one patient received an integral dose as high as 535 kg rad. This integral dose is approximately 50 times higher than that for examination of the upper gastrointestinal tract using video fluoroscopy and 70 mm fluorography (CARLSSON & LAUDE 1968). Although there are no recommendations by ICRP for permissible doses to the patient and there may be cases in which the diagnosis cannot be made without extensive angiographic examinations, the radiologist additionally to the use of automatic exposure controls, should always employ careful collimation, limit the fluoroscopy time and use proper filming programs to avoid unnecessary exposures. Nevertheless, in teaching institutions the doses to the patient tend to be higher than in other departments of radiology as a relatively high number of diagnostically complicated cases are examined and because of teaching programs involved (CARLSSON 1965). The patient who received the integral dose of 535 kg rad was examined with repeated injections into the visceral arteries and serial radiography using stereo tube and 30 cm \times 30 cm field size.

Determinations of integral dose are important for epidemiologic investigations with special regard to the possible influence of the hematopoietic system from repeated small doses of ionizing radiation (NEBOSCHIEW & SCHOTT 1959, GOLDMAN *et coll.* 1960, CARLSSON 1965). Recently GIBSON *et coll.* (1972) found evidence that there is an enhanced risk for males for myeloid leukemia from diagnostic radiology, that this effect is more marked for irradiation of the trunk and increases with the number of films made. GIBSON's report provides further support to the previous investigations on this subject (STEWART *et coll.* 1958, 1962) and stresses the importance of the use of examination techniques requiring a low exposure. In examination of the gastrointestinal tract and in hysterosalpingography substituting 70 mm fluorography for ordinary radiography will yield a reduction of integral dose to approximately 13 to 30 per cent (BANG & LAUDE 1967, CARLSSON & LAUDE 1968). In cardioradiography of adults the use of 70 mm fluorography reduced the integral dose to 32 per cent.

of that required for serial radiography although a larger number of films per examination were made with 70 mm technique. As in certain angiographic examinations the image quality of 70 mm fluorograms is comparable with that of serial radiography the method should be used increasingly in cardioangiography and coronary angiography in which fluorography has the particular advantage of a short exposure time (BOJSEN et coll 1969 KAUDE & HOLM 1971 PINET et coll 1971 HOLM & KAUDE 1972 KAUDE 1973).

In adults the integral dose ratio per film or frame was the same as the exposure ratio for the 3 filming systems used: serial radiography 0.70 kg rad/film, 70 mm fluorography 0.073 kg rad/film (exposure 1/10 of that required for serial radiography), 35 mm cinefluorography 0.013 kg rad/frame (exposure 1/50 of that for serial radiography). The total integral dose however did not decrease by a factor of 10 or 50 as more frames were made using serial fluorography or cinefluorography. The integral dose from one minute videofluoroscopy (0.70 kg rad) was the same as from the exposure needed for one full size film.

In children, the integral doses were lower because of lower exposure required and smaller field size. The integral dose ratio however was approximately the same as in adults: 0.15 kg rad/film in serial radiography and 0.0037 kg rad/frame in 35 mm cinefluorography (70 mm fluorography not used in children). The integral dose rate in videofluoroscopy was also lower (0.17 kg rad/min) but the ratio integral dose per full size film/one minute fluoroscopy remained 1:1. Thus it would be possible to perform one minute videofluoroscopy with the same integral dose as delivered by the exposure needed for one full size film. As the new generation image intensifiers with cerium iodide input screen together with modern video tape recorders offer an excellent image quality considerable savings in dose would be made by substituting videofluoroscopy with simultaneous video tape recording for filming, at least in some examinations of the heart and great vessels.

The personnel. The dose to the eyes (forehead) of the radiologist from the undercouch tube in the report by WOLD et coll (1971) was 25 mR, and it has been postulated that the use of an overhead tube for fluoroscopy would increase the dose to the personnel and the patient (VIAHOMYR 1971). In the present investigation the dose to the eyes of the radiologist from the overhead tube was not measurable. Thus the installation of the roentgen tube above the patient did not result in higher doses to the personnel probably because we used lead rubber drapes at examination.

In cardioangiography the absorbed doses to the fingers of the radiologist were higher than those to the wrist measured by ARIDAN & FURSDON (1973). Nevertheless they remained well below the permissible doses (75 rad) recommended by ICRP (1966) even if all angiographic examinations (in our

department some 1 500 per year) would be performed by the same radiologist.

We agree with ARDREAN & FURSDON that the doses determined by MALIKY *et coll.* (1971) were unnecessarily high and that—good examination technique and radiation protection provided—it is not necessary to rotate radiologists in cardiac (and neither in abdominal) angiography. In the practical work, anyway, not all angiographic examinations will be performed by one and the same radiologist.

The mean absorbed dose to the fingers of the pediatric nurse (right 75, left 89 mrad, the highest dose measured 760 mrad) makes rotation of this auxiliary personnel necessary in order to avoid their classification as radiologically employed personnel (permitted absorbed dose to the fingers for non radiologically employed personnel is 7.5 rad per year ICRP 1966).

Conclusions

With regard to the important for the treatment of the patient often decisive diagnostic information which can be obtained by angiography, a relatively high integral dose has to be accepted in some examinations. For reduction of the integral dose, the number of films should be limited, primary collimation carefully used and the time for fluoroscopy kept short. Further dose reduction is possible by substitution of serial fluorography or fluoroscopy with simultaneous video tape recording for other filming systems. The gonad dose to the patient can be reduced effectively by shielding. From radiation protection point of view, there is no need to rotate radiologists performing angiography, the cardiologist attending or the radiology technician. A pediatric nurse holding a child during angiography should not participate at more than approximately 80 examinations per year. The use of an overhead tube for fluoroscopy and fluorographic recording does not result in excessive radiation of the personnel or of the patient. These conclusions are valid for the type of equipment and examination technique used in the present investigation.

Acknowledgement

We are indebted to Dr Wagner-Mortenson and Dr Thure Mith for help and assistance in dose measurements in children. We thank Prof Carl Castrén for his advice and interest in the present investigation which was supported by grant of the Medical Faculty, University of Lund.

SUMMARY

Measurement of absorbed and integral doses to the patient and personnel from angiographic procedures are reported, the results are discussed and measures to reduce the dose suggested.

ZUSAMMENFASSUNG

Es wird über die Messungen der absorbierten und Integral Dosen für Patienten und Personal bei angiographischen Untersuchungen berichtet. Die Ergebnisse werden besprochen und Vorschläge zur Herabsetzung der Strahlenbelastung werden vorgeschlagen.

RÉSUMÉ

Les auteurs présentent les mesures de doses absorbées et de doses intégrales à malade et au personnel au cours des examens angiographiques. Ils examinent ces résultats et proposent des mesures pour réduire ces doses.

REFERENCES

- ARMSTRONG M and FLEISCH P S. Radiation exposure to personnel during cardiac catheterization. *Radiology* 106 (1973) 517.
- HANELL J, EMMETT-ROBERTS E and OLIVER R. Radiation dose to the patient in cardiac radiology. *Brit J Radiol* 43 (1970) 391.
- BLUM I and HAUTE J. Integral dose in hysterosilpneurography performed with full size radiography and 70 mm fluorography. *Radiology* 7 (1967) 275.
- BORGERT E, HOLM TR and HAUTE J. Comparative angiographic studies using 70-mm intensifier fluorography and aerial film. *Anger Medica mundi* 14 (1969) 120.
- BRONSTEIN L, DABLIN H, CATTANOW M and VITEN O E. Lens doses in carotid angiography. *Acta radiol Diagnos* 12 (1972) 154.
- CARLSON C. Determination of integral absorbed dose from exposure measurements. *Acta radiol Ther Phys Biol* 1 (1963) 433.
- Integral absorbed doses in roentgen diagnostics. A theoretical analysis and clinical application. *Acta Univ. Lundensis. Series II* (1964) No 18.
- Integral absorbed doses in roentgen diagnostic procedures. II. Measurement of integral doses in the roentgen diagnostic departments. *Acta radiol Ther Phys Biol* 3 (1963) 384.
- and HAUTE J. Integral dose in 70 mm fluorography of the gastrointestinal tract. *Acta radiol Diagnos* 7 (1968) 84.
- SÄVJÖ P och SVANÖ G. Stråldoser till patienten och röntgenpersonal vid angiografi. (In Swedish.) I paper presented at 31 Congr. Nordic Soc. Medical Radiology. Reykjavik 1971. Book of Abstr. p. 49.
- CHAMBERLIN R, GRAHAM S, LILIENTHAL A, SCHULMAN L, DOWD J E and LIPPIN M L. Irradiation in the epidemiology of leukemia among adults. *J. nat. Cancer Inst.* 48 (1972) 301.
- GOLDMAN S, LOEWEN W and WOLF R. Messungen zur Integraldosis bei Röntgenuntersuchungen des Thorax und Abdomens Erwachsener im Hinblick auf das Leukamieproblem. *Fortschr. Röntgenstr.* 93 (1960) 269.
- GOLDBERGER J H, DART R and STACEY A J. Radiation doses delivered to the stem bone marrow and gonads of patients during cardiac catheterization and angiocardiology. *Brit J Radiol* 41 (1968) 508.
- HAWKINS I F JR, VICTORICA B E and ELLIOTT L P. Angiocardiography in infants and children. *Crit Rev Radiol Sci* 1 (1970) 311.
- HOLM TR and HAUTE J. Aufnahmen von Bildvermarker. Die Angiographie im Rahmen der klinischen Indikationen. *Röntgen Bl.* 23 (1972) 404. Press. Oxford 1966 p. 10. ICRP Publication 9 Pergamon.

- KAUDE J. Integral dose in 35 mm cinefluorography of the gastrointestinal tract. *Acta radiol Diagnost* 7 (1968) 170
- Koronarographie mit 70 mm Aufnahmen vom Bildverstärker. In: *Angiographie und ihre neuesten Erkenntnisse*. Herausgegeben von K. E. Loose. Walter de Gruyter, Berlin 1973
 - CARLSSON C. und SPANNE P. Patientendosis und Strahlenbelastung des Röntgenpersonals bei angiographischen Untersuchungen. In: *Angiographie und ihre Fortschritt*. S. 26. Herausgegeben von K. E. Loose. Georg Thieme, Stuttgart 1972
 - und HOLM T. Bildverstärker und Aufnahmen. *Deutscher Röntgenkongress* 1971. Fortsch. Röntgenstr. Suppl. 1972 S. 136
- LARSSON L. E. Radiation doses to the gonads of patients in Swedish roentgen diagnostics. *Acta radiol* (1958) Suppl. No. 157
- MALEY S. J., ROWATT B., REID C. B. and HART J. Radiation exposure to personnel during cardiac catheterization. A preliminary study. *Radiology* 100 (1971) 671
- NEBOKJEN A. und SCHOTT O. Zur Überwachung der Patientenbelastung während der Röntgendurchleuchtung. *Röntgen Bl.* 12 (1959) 244
- PIVET F., AMIEL M., RUBET A. et DALAYE J. Intérêt d. format 70 mm dans l'artériographie coronaire. *Ann. Cardiol. Angéol.* 20 (1971) 5
- STEWART A., PENNYBAKER W. and BARBER R. Adult leukaemias and diagnostic x-rays. *Brit. J. Med.* 2 (1962) 882
- WEBB J. and HEWITT D. A survey of childhood malignancies. *Brit. J. Med.* 1 (1958) 1495
- STEVE F. E. Aktuelle Strahlenschutzprobleme in der Röntgendiagnostik. GSF Bericht K. 57. Neuherberg 1969
- Strahlenschutz in der Röntgendiagnostik. Bericht aus Inst. Physik. Ther. Röntgenol. Univ. München 1969
- VANOMTZE J. M. Jr. Practical aspects of special procedures: equipment and personnel. Paper presented at the 57 Scientific Assembly and Annual Meeting, RSNA, Chicago 1971. *Book of Abstracts* p. 28
- WACHSMAN F. Probleme der Patientendosimetrie. *Röntgen Bl.* 15 (1962) 113
- WOLD G. J., SCHIELE H. V. and AGARWAL S. K. Evaluation of physician exposure during cardiac catheterization. *Radiology* 99 (1971) 188

RÖNTGEN AND THE NOBEL PRIZE

The discussion at the Royal Swedish Academy of Sciences
in Stockholm in 1901

FOLKE KNUTSSON

The deliberations at the Academy of Sciences that led to the award of the first Nobel Prize in Physics to Wilhelm Conrad Röntgen in 1901 have previously been kept secret. Now that the minutes have been released, it has become possible to form an idea of how the most prominent scientists of the day in the field of physics assessed the significance of Röntgen's discovery.

Those authorized to propose candidates for the prize were the members of the Academy of Sciences and the Swedish professors of physics. A number of other authorities in the field of physics in different parts of the world had also been invited to proffer suggestions. When the time for nominations had expired 29 proposals had been submitted: 12 of them suggesting Röntgen, 1 Ph. Lenard and 5 a division of the prize between these two scientists. Nine other candidates were also mentioned, but each of these had only received one or at the most two votes. In consideration of the great variety of these suggestions the overwhelming majority for Röntgen was thus quite clear. It is especially interesting to note that the advisory committee of experts attached to the Academy, the Nobel Committee for Physics, recommended that the prize be divided equally between

From the Department of Diagnostic Radiology (Director Prof. H. Lodin), Akademiska sjukhuset, Uppsala University, S-750 14 Uppsala, Sweden. Submitted for publication 22 February 1974.

- LAUDE J. Integral dose in 35 mm cinefluorography of the gastrointestinal tract. *Acta radiol Diagnos* 7 (1968) 170
- Koronarographie mit 70 mm Aufnahmen vom Bildverstärker. In: *Angiographie und ihre neuesten Erkenntnisse* Herausgegeben von K. E. Loose. Walter de Gruyter Berlin 1973
 - CARLSON C. und SPANOK P. Patientendosis und Strahlenbelastung des Röntgenpersonals bei angiographischen Untersuchungen. In: *Angiographie und ihre Fortschritte* S. 26 Herausgegeben von K. E. Loose. Georg Thieme Stuttgart 1972
 - und HOLM T. Bildverstärker und Aufnahmen. Deutscher Röntgenkongress 1971. *Fortchr. Röntgenstr. Suppl.* 1972 S. 136
- LARSON L. E. Radiation dose to the gonads of patients in Swedish roentgen diagnostics. *Acta radiol.* (1958) Suppl. No. 157
- MALIKY S. J., ROSEY B., REID C. B. and HART J. Radiation exposure to personnel during cardiac catheterization. A preliminary study. *Radiology* 100 (1971) 671
- NEBOCHIEV A. und SCHOTT O. Zur Überwachung der Patientenbelastung während der Röntgendurchleuchtung. *Röntgen* III 12 (1959) 244
- PIRET F., AMIEL M., RUBET A. et DALAYZ J. Intérêt du format 70 mm dans l'artériographie coronaire. *Ann. Cardiol. Angéiol.* 20 (1971) 5
- STEWART A., PRONYAIKER W. and BARBER R. Adult leukaemia and diagnostic x-rays. *Brit. J. Med.* 2 (1962) 882
- WELLS J. and HEWITT D. A survey of childhood malignancies. *Brit. J. Med.* 1 (1958) 1495
- STIEVE F. H. Aktuelle Strahlenschutzprobleme in der Röntgendiagnostik. GSF Bericht Nr. 57. Neuberger 1969
- Strahlenschutz in der Röntgendiagnostik. Bericht aus Inst. u. Polikl. f. phys. Ther. u. Röntgenol. Univ. München 1969
- VANONYE J. M. Jr. Practical aspects of special procedures: equipment and personnel. Paper presented at the 57 Scientific Assembly and Annual Meeting, RSNA, Chicago 1971. *Book of Abstr.* p. 28
- WACHSMAN F. Probleme der Patientendosimetrie. *Röntgen* III 15 (1962) 113
- WOLD G. J., SCHIFFELS R. V. and AGARWAL S. K. Evaluation of physician exposure during cardiac catheterization. *Radiology* 99 (1971) 188



W. Röntgen

thus had had all the prerequisites enabling Röntgen to discover the new radiation.

It is of interest to mention here an experiment which led to undoubted roentgen radiation but not to its discovery. On 22 February 1890 Professor A. W. Goodspeed and a photographer named W. N. Jennings were carrying out photographic experiments at the Institute of Physics at the University of Pennsylvania in Philadelphia using as a light source the sparks in a vacuum tube. After the developing work, they noticed a couple of very mysterious discs on a plate that had been lying in the room but had not been used. No explanation of the phenomenon could be found. The plate was saved. Not until after Röntgen's discovery six years later did it become obvious that the picture was in reality a roentgen image and that its appearance was to be explained by the fact that two coins had been lying on the plate.

At the time when Röntgen was awarded the Nobel Prize scientists in many parts of the world had for six years known about the discovery of the new form of radiation and they had realized that it would be of great significance to technical research and the medical sciences. Although it was hardly possible at

that time to foresee the immense influence the discovery was to have on future developments it seemed quite natural that Rontgen should be proposed as a candidate for the Nobel Prize at the first conferment.

W. C. Rontgen was one of the scientists who had been invited to submit names for the prize. He suggested that Lord Kelvin (1824—1907) in Edinburgh would be a suitable candidate because of his extensive and important contributions in different fields in the science of physics. The inquiry into his merits revealed, however, that his work had been carried out at such an early date that he could not, according to the statutes, be considered eligible.

The Academy of Sciences is the authority that awards the prize in physics, and the Nobel Committee for Physics has the task of examining the proposals sent in and of presenting a suggestion as to a suitable prizewinner. The Committee was composed of five members, and during the discussions at its meetings it was decided that a division of the prize between Rontgen and Lenard should be recommended. The two committee members Arrhenius and Ångström were instructed to draw up the reasons for this decision.

Of the foreign experts who had been invited to propose candidates 12 had voted for Rontgen. None of them had made an exhaustive assessment of the scientific purport of his discovery, nor compared its significance with the results of other research work in progress in the field of physical science. They considered quite simply that Rontgen's contribution was so well known that no further comments were needed, and as a consequence their proposals were of no definite assistance as a guide for the Committee. Lenard was proposed by S. P. Thompson in London, who, in justifying his choice, presented a detailed account of this scientist's work with cathode rays.

The report presented by the Committee is given here in translation. The italics have been added by Knutsson.

To the Royal Swedish Academy of Sciences

After having examined the merits of the candidates proposed for the Nobel Prize in Physics for the year 1901 the undersigned members of the Nobel Committee for Physics of the Academy of Sciences have the honour to recommend that, for the reasons given below, the prize in question be divided equally between

Prof. W. C. Rontgen, Munich and Prof. Ph. Lenard, Kiel

Stockholm 9 Sept. 1901

C. B. Hasselberg
Knut Ångström
Rob. Thalen

H. H. Hildebrand
Svante Arrhenius

The scientific discovery which qualifies Professor Röntgen to a higher degree than others for selection at the first conferment of the Nobel Prize in Physics is so well known that a more detailed account of it would not seem to be necessary. Professor Röntgen at the end of the year 1895 handed to the Würzburger Phys. Med. Gesellschaft a paper entitled *Über eine neue Art von Strahlen* which was followed at the beginning of 1896 by another paper *Erne neue Art von Strahlen II Mitteilung* and in 1897 by still another *Weitere Beobachtungen über die Eigenschaften der X-Strahlen*. These small treatises give an account of Röntgen's discovery of the rays to which he gave the name of X-rays and they also contain all the most important features of what is known today about this extraordinary phenomenon. This discovery was of the greatest importance from the purely scientific point of view as it increased our knowledge by presenting information on a phenomenon that hitherto has completely escaped our notice and has opened up a new field offering undreamt of possibilities for scientific research. Its practical results also were of great importance. It could therefore be said of this discovery with full justification that it has rendered the greatest service to mankind and that to award it the Nobel Prize would be fully in accord with the intentions of the founder.

From this it also emerges that Röntgen's discovery is in our view of such great value that there would be every reason for awarding it the Nobel Prize without division.

Nevertheless we take the liberty of recommending that the Nobel Prize in Physics be shared this year between Professors Röntgen and Lenard. As will be seen from the following arguments the latter through his investigations into the properties of the cathode rays paved the way for Röntgen's discovery and thereby made a purely scientific contribution of such importance that it is fully equal to Röntgen's observations which on the other hand surpass those of Lenard because of their practical applications. When scrutinizing the merits of these two scientists we have found it difficult to decide which of them should be considered on the basis of their investigations the most worthy to receive the Nobel Prize in Physics if it were to be awarded to one of them alone and even more so as their discoveries are so intimately interconnected. That opinions have previously on similar occasions been in agreement regarding the scientific equality of these two research workers is clear from the fact that the Academy of Sciences in Vienna in 1896 divided the Baumgarten Prize equally between them and that the Paris Academy in 1898 awarded two La Caze Prizes one to Röntgen and the other to Lenard.

Already at an earlier date Crookes, Hittorf and others had made a thorough study of the cathode rays but in their investigations the rays could only be examined in the actual discharge tube a procedure that obviously caused con-

considerable difficulties. Hertz, however, demonstrated that cathode rays penetrate thin layers of metal and this observation caused Lenard to think that it might be possible to obtain cathode rays outside the discharge tube by arranging on the tube a window hermetically sealed by a membrane penetrable by these rays. On 12 January 1893 Lenard handed to the Berlin Academy a preliminary report on his experiments, entitled *Über Kathodenstrahlung in Gasen von atmosphärischem Druck und im aussersten Vacuum* (Wied Ann 51 1894). This was followed by his doctoral thesis, *Über die magnetische Ablenkung der Kathodenstrahlen* (Wied Ann 52 1894) and by a third paper *Über die Absorption der Kathodenstrahlen* (Wied Ann 56 1895). In these treatises, which all preceded Röntgen's discovery, Lenard demonstrated that cathode rays can be produced outside the discharge tube, and there he also investigated their leading properties. He examined the absorption and diffusion ability of different bodies, demonstrated how cathode rays give rise to phosphorescence, and showed that the rays have an effect on a photographic plate even when it is protected from the influence of visible light. He also proved that there are different types of cathode rays that these rays are influenced to different degrees by magnetic forces, and that their nature alters with the attenuation in the discharge tube. Furthermore he produced for the first time with the aid of a magnet a simple spectrum of the cathode rays. As Lenard had varied the pressure in the discharge tube from the most extreme attenuation when discharge is prevented to the highest degree of pressure there seems to be little doubt that he was already dealing with Röntgen's λ rays although their differentiation from the cathode rays had escaped his attention. The credit for their detection thus belongs to Röntgen. It is obvious however that Lenard was very close to a discovery of the λ rays and that he should undoubtedly be counted as Röntgen's most important forerunner. Professor Lenard subsequently continued his valuable investigations on the cathode rays and on questions connected with them. A few of his other publications may be mentioned.

Über die elektrostatichen Eigenschaften der Kathodenstrahlen (Wied Ann 64 1898)

Über das Verhalten von Kathodenstrahlung parallel zu elektrischer Kraft (Wied Ann 65 1898)

Erzeugung von Kathodenstrahlen durch ultraviolettes Licht (Sitz ber d k Akad in Wien Okt 1899)

Über Wirkungen des ultravioletten Lichtes auf gasförmige Körper (Drudes Ann 1 1900)

Über die Elektricitätsvertheilung in ultraviolett durchstrahlter Luft (Drudes Ann 3 1900)

In view of the above arguments the proposal advanced here would seem to be fully justified.

Comment

Thus the Nobel Committee, in its communication to the Academy of Sciences established that Röntgen's discovery provided knowledge about a previously unknown phenomenon had opened up a new field for research work and had had important practical results. It also pointed out that the credit for the differentiation of the X rays from the cathode rays belonged wholly to Röntgen. Because of the great significance of the discovery it undoubtedly deserved in the opinion of the Committee to be awarded an undivided Nobel Prize. This was thus an unmistakable alternative to the suggestion as to division of the prize that was finally put forward by the Committee.

The Committee had found that Lenard's systematic research into the properties of the cathode rays constituted a feat of such importance in itself that it was comparable to Röntgen's discovery and that in consequence it was hard to decide which of the two scientists should be preferred if the prize were to be awarded to one of them alone. The choice was the more difficult because Lenard's research results had presumably been of considerable value in the experiments that led Röntgen to his discovery. The Committee therefore considered it necessary to stress that Lenard's work had paved the way for Röntgen's experiments. When this point had been made clear the natural consequence was to propose the alternative that the prize be divided between them.

No minutes were kept at the meetings of the Academy of Sciences at which the Nobel Committee's proposal concerning the physics prize was discussed. A wish that the prize should preferably be awarded to one candidate alone was obviously expressed during the deliberations, since according to a memorandum Arrhenius had remarked that Röntgen should be mentioned before Lenard. At a meeting on 12 November 1901 the Academy in plenary session decided to award the prize to Röntgen. The Academy thus disregarded the recommendation of the committee of experts. Whether the Academy would have acted in a similar way today or would have followed the suggestion of the committee remains open for discussion. It can however be established that no circumstances likely to be of significant assistance in simplifying this problem have come to light in the intervening period.

The award of the Nobel Prize meant that Röntgen was honoured by a representative forum of the physical sciences. Lenard (1862-1947) the professor at Kiel felt that his work had been underestimated and took exception to the honour that had been paid to Röntgen. He maintained that it was he who had been the first to observe the new form of radiation. The opposition began in connection with the presentation of the Nobel Prize. Previously fairly friendly relations had existed between the two men and no written criticism was advanced by Lenard. Glaeser has described Lenard's campaign after examining

the rumours that had been circulating and the written evidence available, and from a correspondence with Lenard in order to obtain information on the historical background. Glasser concluded that there were no well founded motives to account for the hostile criticism directed against Röntgen. Lenard however continued the controversy throughout the rest of his life, despite the fact that he was awarded the Nobel Prize in Physics in 1905 for his work on the cathode rays. Even as late as in 1944 when he was 82 years old he reverted to the matter in a bitterly critical article in which he used a parable with the following import: Röntgen was the assistant at the delivery and thereby was the first to be able to hold up the child for inspection. Lenard, on the other hand, was the mother who possessed the knowledge of all that had gone before.

Lenard was not able to advance convincing arguments capable of discrediting Röntgen's achievement and thus did not succeed in depriving him of the credit for the discovery. It is to be regretted that he never learned of the pronouncement made in 1901 by the experts on the Nobel Committee, pointing out that Lenard's research results must be acknowledged as being of such fundamental significance to the discovery by Röntgen that the physics prize ought to be divided equally between them. As a consequence, he had no opportunity to make use of this opinion and thus missed having for his campaign a much more powerful argument than the unconvincing ones that were adduced.

SUMMARY

The discussions carried on at the Swedish Academy of Sciences when the Nobel Prize in Physics was awarded for the first time in 1901 have hitherto been kept secret. The Nobel Committee for Physics attached to the Academy consisting of five experts considered that among all the candidates proposed Röntgen and Lenard were the most worthy to receive the distinction and recommended that the prize be divided equally between them. In the discussions at a plenary meeting of the Academy the wish seems to have been expressed that the prize should if possible be awarded to one scientist alone and it was decided to give it to Röntgen for his discovery of the ray that bears his name. Lenard who remained unaware of the recommendation made by the Nobel Committee that the prize be shared between him and Röntgen considered that Röntgen had been unjustly given the entire credit for the discovery. For the rest of his life he maintained that the importance of his own contribution to the discovery had been undervalued.

ZUSAMMENFASSUNG

Die in der Schwedischen Akademie der Wissenschaften geführten Diskussionen als der Nobelpreis für Physik zum ersten mal 1901 zuerkannt wurde sind bisher geheim gewesen. Das Nobelkomitee für Physik das der Akademie zugehört und aus fünf Experten bestand beurteilte unter allen vorgeschlagenen Kandidaten Röntgen und Lenard als die würdigsten die Auszeichnung zu erhalten und empfahlen den Preis zwischen diesen beiden gleich zu

teilen. In der Diskussion der Planansetzung der Akademie scheint der Wunsch ausgedrückt worden zu sein, der Preis solle wenn möglich nur einem Wissenschaftler alleine zuerkannt werden und es wurde entschieden ihm Röntgen für seine Entdeckung der Strahlen die seinen Namen tragen zu geben. Lenard dem die Empfehlung des Nobelkomitees dass der Preis zwischen ihm und Röntgen geteilt werden soll unbekannt blieb sah an dass Röntgen die ausschließliche Ehre für die Entdeckung ungerechtfertigt zuerkannt worden sei. Für den Rest seines Lebens hob er hervor die Bedeutung seines eigenen Beitrags zur Entdeckung sei unterbewertet worden.

RÉSUMÉ

Les discussions qui ont eu lieu à l'Académie Suedoise des Sciences quand le Prix Nobel de Physique a été attribué pour la 1^{re} fois en 1901 ont jusqu'à maintenant été tenues secrètes. Le Comité Nobel pour la physique avait l'Académie composée de 5 experts considérant que parmi tous les candidats proposés Röntgen et Lenard étaient les plus dignes de recevoir cette distinction et recommanda que le prix fut divisé également entre eux. Au cours des discussions à la réunion plénière de l'Académie le vote sembla avoir été exprimé que le prix devait si possible être attribué uniquement à l'un d'eux et il fut décidé de le donner Röntgen pour sa découverte des rayons qui portent son nom. Lenard qui resta mécontent de la recommandation fait par le Comité Nobel que le prix fut partagé entre lui et Röntgen considéra que tout le mérite de la découverte avait été injustement attribué Röntgen. Pendant tout le rest de sa vie il soutint que l'importance de sa contribution personnelle à la découverte avait été sous-estimée.

REFERENCES

- Les prix Nobel en 1901. P. A. Norstedt & Söner Stockholm 1904.
 GLASSER, O. Wilhelm Conrad Röntgen. Springer Verlag Berlin Göttingen Heidelberg 1959.
 STRANDBY, N. The physics prize Nobel the man and his prizes Elsevier publ. comp. Amsterdam 1967.
 Minutes from the meetings of the Nobel Committee for Physics on Feb. 2, 1901, 7 and Sept. 8 Stockholm 1901.

SELECTIVE PHLEBOGRAPHY OF THE PANCREAS

J. GÖTHLIN, A. LUNDBERQUIST and U. TILLY

Angiography of the pancreas has solely been based on selective examination of the celiac and superior mesenteric arteries and their branches, since a method for venous approach has not been available. Catheterization of the portal vein via the umbilical vein in adults is now an established method and at transhepatic cholangiography portal vein branches are often punctured.

Using the umbilical vein approach of the portal vein in portography for liver metastases pancreatic veins were accidentally found available for selective catheterization. This was the increment for a planned investigation of the pancreatic vein, now presented as a preliminary report.

Anatomy. The venous drainage of the head of the pancreas is constituted by four main veins forming two arcades, one posterior and one anterior (Fig. 1). The posterior superior pancreatico-duodenal vein drains the posterior arcade into the portal vein. The entry of this vein is at the inferior posterior aspect usually about 2 cm from the point where the portal vein arises from the superior mesenteric and splenic veins. The posterior arcade also empties into the first jejunal vein via the posterior inferior pancreatico-duodenal vein.



Fig 1 Venous anatomy of the pancreas derived from dissection PSPD = posterior superior pancreaticoduodenal vein ASPD = anterior superior pancreaticoduodenal vein GDT = gastroduodenal vein PIPD = posterior inferior pancreaticoduodenal vein AIPD = anterior inferior pancreaticoduodenal vein TP = transverse pancreatic vein

The anterior arcade is formed by the anterior superior pancreaticoduodenal vein and the anterior inferior pancreaticoduodenal vein. The former empties into the superior mesenteric vein at its right lateral aspect after having joined the right gastro-epiploic and right colic veins to form the gastro-colic trunk. The anterior inferior pancreaticoduodenal vein empties into the first jejunal vein often after having formed a common inferior pancreaticoduodenal vein together with the posterior inferior pancreaticoduodenal vein (DESCOMPS & LALAUBIE 1912; PETER 1929; DOUGLASS et coll 1950; FALCOVER & GRIFFITHS 1949).

The body and tail of the pancreas are drained by the transverse (inferior) pancreatic vein passing at the inferior posterior surface of the pancreas. It either empties directly into the superior or inferior mesenteric vein at their left lateral aspect. Several small veins with individual entry into the splenic vein also collect the blood from the body and tail of the pancreas (DOUGLASS et coll; FALCOVER & GRIFFITHS).

Material and Methods. The pancreatic veins were selectively catheterized in 40 patients, 33 of whom with a malignant tumour outside the pancreaticoduodenal area for example the colon. They were referred for portography to demonstrate possible liver metastases; the transumbilical technique was used. These patients constitute the control series.

The remaining 7 patients were examined with the transhepatic catheterization technique. The patients had jaundice and were referred for percutaneous transhepatic cholangiography. Four of these patients had carcinoma of the bile ducts without involvement of the pancreas at operation; two patients had carcinoma of the pancreas subsequently verified at surgery and one patient with portal hypertension was examined during portography.

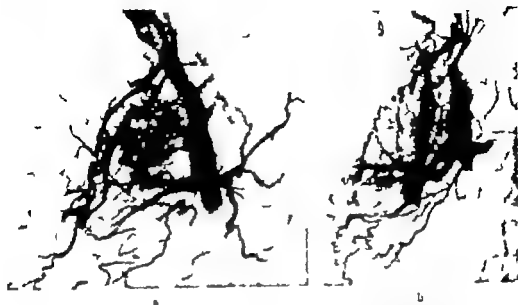


Fig. 7. Normal phlebographic anatomy of the pancreas. (a) and (b) right posterior oblique views. Catheter is posteriorly up main pancreatico-duodenal vein filling of posterior and anterior tributaries emptying in superior pancreatico-duodenal vein and SA troncic trunk.

Technique

The selective catheterization of the pancreatic veins was performed via two different routes.

Transumbilical approach The remnant of an umbilical vein is operatively dilated by a probe and a soft catheter introduced into a branch of the left portal vein. The patient is then brought to the department of diagnostic radiology. During fluoroscopy a guide wire is introduced into the main branch of the left portal vein. The guide wire has a sharp bend at the tip and can therefore be manipulated down into the main stem of the portal vein. The operatively introduced catheter may then be changed to a thin walled catheter (OD/ID 2/1.4 mm) without sideholes. This catheter is preformed with a slight bend of the first 5 cm of the tip. The bend at the tip of the catheter may allow it to be passed along the inferior wall of the portal vein and the pancreatic veins can be catheterized. An introduction of the bent guide wire into the pancreatic vein may facilitate the insertion of the catheter in some cases.

Transhepatic approach The catheter is inserted by the usual technique for transhepatic cholangiography. If the tip of the catheter fails to lie in a branch of the portal vein the catheter is slowly retracted until blood starts to drop and



Fig. 3 Normal phlebography of the tail of the pancreas. Catheter in branch of splenic vein. Transverse pancreatic vein filled through abundant anastomoses in parenchyma.

a few ml of contrast medium are injected for identification of the portal vein. A guide wire is then introduced and manipulated into the main stem of the portal vein. If only a thin branch has been punctured this manipulation may be extremely difficult. A bend on the tip of the guide wire or a J formed guide wire may be of help. Extreme care must be taken not to injure the liver parenchyma or displace the tip of the catheter. After the guide wire has been passed down into the portal vein the catheterization of the pancreatic veins is performed in the same way as with the transumbilical technique.

After entering a pancreatic vein 10 ml of Iopaque Coronar (Negaard) are injected by hand taking care that the catheter is not wedged in the small veins. Two films per second are exposed during 3 seconds in a p. and right posterior oblique projections. The catheter is then withdrawn to the portal vein and 40 ml of the contrast medium injected to demonstrate possible involvement of portal or superior mesenteric veins or liver metastases.

Results

The posterior superior pancreatico-duodenal vein was catheterized in 33 patients, the anterior superior pancreatico-duodenal vein in two and veins from the body and tail of the pancreas in four patients. In one additional patient filling of venous arcades was obtained by injection of contrast medium into the extra-colic trunk. The normal anatomy of the pancreatic veins at phlebography is illustrated in Figs 2 and 3. The veins had a different appearance in two patients with pancreatic carcinoma. In one patient several venous branches were obstructed and others appeared irregularly invaded by a neoplasm which was small and resectable (Fig. 4). The other patient had an inextirpable tumour

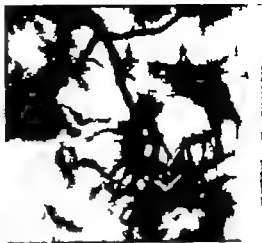


Fig. 4. Phlebography in carcinoma of the head of the pancreas. Catheter in posterior superior pancreaticoduodenal vein. Filling and occlusion of branches (\rightarrow). Draining catheter too in common bile duct.

which invaded the portal vein. Catheterization of the posterior superior pancreaticoduodenal vein was possible but the vein was compressed by the tumour and filling of other veins in the region of the head of the pancreas was not obtained.

Complications. Pancreatic phlebography with the transumbilical technique was performed without other complications than small extravasations which occurred in two patients. In one of these injection of the contrast medium was performed with the catheter in wedged position. The extravasation encountered required no treatment. Two of the seven transhepatically catheterized patients required emergency operation because of intraabdominal bleeding.

Discussion

The catheterization of pancreatic veins is more easily performed by the transhepatic than by the transumbilical approach. The reason is that with the former technique the catheterization is made in the direction of the catheter while the latter will require the catheter to be pushed round the sharp bend formed by the left branch and the main stem of the portal vein. With some experience catheterization seems to be possible in most patients. The posterior superior pancreaticoduodenal vein is most easy to enter. Sometimes, however, this vein joins the portal vein at an acute angle and then it may be difficult to obtain a stable position of the catheter. A bend of the tip of the guide wire may facilitate the introduction of the tip of the catheter deeper into the vein in such cases.

Since there are abundant anastomoses between the posterior and anterior arcades most of the veins in the head of the pancreas including the inferior pancreatico-duodenal vein are demonstrated by injection into the posterior superior pancreatico-duodenal vein. In some cases however only filling of the veins of the posterior part of the head is obtained. In such cases and in cases where catheterization of the posterior superior pancreatico-duodenal vein is impossible the anterior superior pancreatico-duodenal vein should be examined as well. Catheterization and injection of contrast medium into the gastro-colic trunk however generally demonstrate only gastric and colonic veins and only seldom permit filling of the pancreatic veins. The catheter therefore must be placed selectively in the anterior superior pancreatico-duodenal vein. Again bending of the tip of the guide wire generally makes it possible to enter also this vein.

In our experience the catheterization of the veins from the body and tail of the pancreas entails more difficulties because the veins are small and the anatomy variable. This however is probably just a matter of experience.

The transjugular approach for catheterization of the portal vein (HANAFEE & WEINER 1967) could possibly be used also for selective catheterization of the pancreatic veins and may be as convenient as the transhepatic one but has not been tried by us.

The venous anatomy as revealed by dissection seems to be valid in most cases. In the head of the pancreas however many variations occur and in this material two posterior superior pancreatico-duodenal veins were more common than might be expected from the literature. An account of the venous anatomy will be given in more detail when more experience has been gained.

The fact that two patients had to be explored surgically because of intra-abdominal bleeding may make the transhepatic approach appear risky. These complications happened early in the series and at that time a red thin walled catheter was introduced into the liver. At present a much thinner catheter is used and evident intraabdominal bleeding has not occurred. The risk of complications of this type may be less with the transjugular technique. Another point worth stressing is that the transhepatic technique was used only in patients with jaundice in whom there is increased risk of bleeding. Drainage of the biliary tract by a percutaneously inserted catheter for some days and pancreatic phlebography in a second session are probably to be preferred. It should not be forgotten also to perform an injection into the main stem of the portal vein as this is of great importance in the evaluation of operability of tumours in this region.

The value of pancreatic phlebography in the diagnosis of lesions in the pancreatico-duodenal region is at present too early to estimate. Theoretically the method should be useful in the diagnosis of carcinoma of the pancreas since the tumour is apt to invade the veins early while the arterial encasement appears

later. Pancreatic phlebography in the differentiation between inflammatory and malignant lesions should also be investigated.

Catheterization of pancreatic veins must definitely be of value in the investigation of patients with islet-cell tumours, in whom blood samples may be collected for analysis of insulin and gastrin.

SUMMARY

A method for selective pancreatic phlebography using the transumbilical or transhepatic approach is described. The results from a material of 40 cases, 2 of whom with carcinoma of the pancreas are presented.

ZUSAMMENFASSUNG

Es ist eine Methode zur selektiven transumbilikalischen oder transhepatischen Phlebographie des Pankreas wird angelegt. Die Ergebnisse in einem Material von 40 Patienten, von welchen 2 Pankreas-Karzinom hatten, werden vorgelegt.

RÉSUMÉ

Présentation d'une méthode de phlébographie sélective du pancréas par voie transombilicale ou transhépatique. Les résultats acquis sur un matériel de 40 malades dont 2 avaient un cancer du pancréas sont donnés.

REFERENCES

- DEGROSS P. et DE LAJALIE G. Les veines mésentériques. *J. Anat. (Paris)* 48 (1912) 337.
 DOUGLASS B. E., B. CGRSTON A. H. and HOLLANDER W. H. The anatomy of the portal vein and its tributaries. *Surg. Gynec. Obstet.* 91 (1950) 562.
 FALLOON C. W. A. and GRANTING E. The anatomy of the blood vessels in the region of the pancreas. *Br. J. Surg.* 37 (1950) 334.
 HANAUER W. and WERN M. Transjugular percutaneous cholangiography. *Radiology* 88 (1973) 33.
 JETRI T. Die Arterien und Venen des Duodenum und des Pankreaskopfes beim Menschen. *Z. Anat. Entwickl. Gesch.* 90 (1911) 234.

ORBITAL PHLEBOGRAPHY

II Anatomy of superior ophthalmic vein and its tributaries

JAN BRISMAR

At orbital phlebography the diagnosis has been based largely upon changes in the appearance of the superior ophthalmic vein except for those comparatively rare cases where tumor veins or venous malformations are demonstrated. It is then surprising that little information is to be gained from the literature concerning the normal variations in the course of the vein if the course is similar in both orbits, the normal width of the vein and if this be related to technical factors at the examination. The reports available are partly contradictory and it is also uncertain what diagnostic value is attached to an incomplete demonstration of the vein. As orbital phlebography is gaining increasing interest the present investigation was undertaken to acquire a deeper knowledge of the anatomy of the superior ophthalmic vein and its variations as a basis for the differentiation between normal and pathologic conditions.

Anatomy

Dissections of the orbital veins were performed by SESEMAN (1869) and GOKWITSCH (1883). The superior ophthalmic vein is the main intraorbital vein.

Submitted for publication 21 December 1973

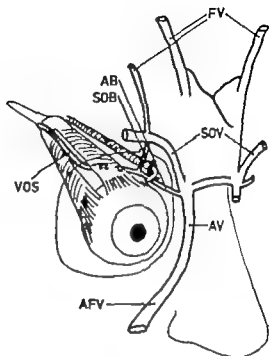


FIG. 1 Superior ophthalmic vein (VOS) and the facial veins near the orbit. Frontal vein (FV), Supraorbital vein (SOV), Angular vein (AV), Anterior facial vein (AFV), Angular (AB) and supraorbital (SOB) tributary branches to superior ophthalmic vein.

and is connected by abundant collaterals directly or indirectly with all other intraorbital veins (GURWITSCH). It is formed closely behind the pulley of the superior oblique muscle by the junction of two branches: one from the supraorbital vein passing through the supraorbital foramen and above the pulley, the other from the angular vein passing along the medial orbital wall and below the pulley (SESEMAN). The latter author stated that both branches were wide but that the supraorbital branch often was the larger one.

The most anterior part of the superior ophthalmic vein lies close to the orbital roof (ARON ROSE *et coll.* 1967). The vein then turns laterally, enters the muscular cone and passes backwards laterally under the superior rectus muscle. It crosses the muscular cone to appear on the lateral side of the superior rectus muscle and continues lateral to the musculus levator palpebrae above the lateral rectus muscle. Approaching the superior orbital fissure the vein turns downwards to pass through the fissure to enter the anterior part of the cavernous sinus (Fig. 1). SESEMAN as well as GURWITSCH mention that the superior ophthalmic vein often is divided into two or even three branches that later join again.

Contrary to the general opinion of that time SESEMAN stated that the width of the vein increased successively as the vein passed backwards through the orbit.

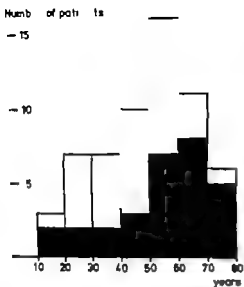


Fig. Age and sex distribution of the material. □ males ■ females

and then considerably decreased as the vein passed through the orbital fissure. Previously a widening of the vein close to the cavernous sinus—a sinus ophthalmicus—had been described. MERRILL (1874) was not able to confirm the opinion of SKEWES. Like previous authors, he found a constant widening of the posterior part of the vein. GURWITSCH stated that following a constant narrowing during the passage through the superior orbital fissure a widening of the lumen as the vein approached the cavernous sinus often occurred thus explaining the earlier differences in opinion.

Methods

The technique used for orbital phlebography is previously described in detail (BRUMER). Only a brief summary will be given here. A teflon cannula is percutaneously inserted into a frontal vein. During compression of the frontal and the angular veins serial films are exposed in five different projections: an a.p. view (angulated 10° from below), one straight lateral and one oblique lateral view and an axial view. One series of films is also exposed in an a.p. view before applying compression. For each series 10 ml of contrast medium (Iopaque cerebral Nyegaard) is injected in approximately 1 s. Photographic subtraction is routinely used. All measurements have been made directly on the films using a scale lupe (7 \times). The focus-film distance has been 100 cm for the a.p. views and 90 cm for the lateral view. The patient's head has always been in direct

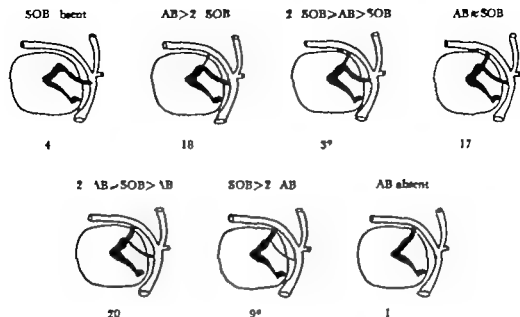


Fig. 3 The diameter of the angular branch (AB) in relation to the diameter of the supra-orbital branch (SOB) of the tributaries to the superior ophthalmic vein

contact with the automatic cut film changer (AOT or PUCK, Siemens Flema). No correction for magnification factors has been made.

Material

The material (Fig. 2) consists of the first 60 patients from the series previously presented (BRISMAR). All patients were referred for possible disorders either intraorbitally or affecting the cavernous sinuses or the adjacent basal venous sinuses of the skull. In nine patients, however, the final clinical evaluation did not support the presumption of such a disorder.

In order to obtain a normal material the total number of 120 orbits of the material had to be reduced by orbits not adequately examined and by those with a clinically possible intraorbital disorder.

Sixty-two orbits remained as the normal material and were referred to two groups as follows:

Group A 42 orbits (both orbits in seven patients) with no clinical signs of disorder affecting the orbit or the cavernous sinus.



b

Fig 4 Different types of origin of the superior ophthalmic vein a) The supraorbital tributaries (\rightarrow) are wide the angular tributaries (\dashrightarrow) narrow Asymmetry of the anterior parts as well as unilateral right sided duplication of the middle part of the superior ophthalmic vein b) Dominant regular tributaries (\dashrightarrow) On the left side small supraorbital branch (\rightarrow) but no supraorbital branch on the right side

Group S 20 orbits in 10 patients with an intrasellar expanding lesion causing compression but not occlusion of the cavernous sinuses. As it could not be excluded that the drainage of the orbital veins through the cavernous sinus was impaired (though a good passage of contrast medium through the cavernous sinus occurred at the phlebography) the groups N and S were evaluated separately for analysis of the width of the superior ophthalmic vein.

Results

Topographic information on the facial veins around the orbits including the tributaries to the superior ophthalmic vein is valuable for the puncture and may be indispensable for the application of digital compression in order to direct the flow of medium into the orbits.

Facial veins These veins were adequately filled with contrast medium in 51 patients allowing an analysis of the venous anatomy in the vicinity of the orbits.

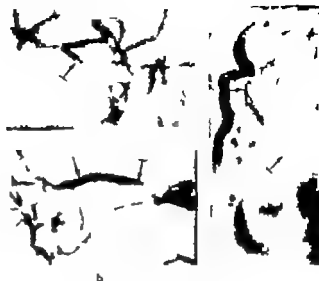


Fig. 1. Phlebographic appearance of the superior ophthalmic vein and its tributaries in (a) frontal view (b) lateral view and (c) anterior view. (a) superior ophthalmic vein (b) anterior ciliary vein (c) posterior ciliary vein (d) superior tarsal vein (e) inferior tarsal vein (f) lacrimal vein (g) supraorbital vein (h) angular vein (i) frontal vein (j) middle temporal vein (k) posterior temporal vein (l) anterior temporal vein (m) posterior frontal vein (n) anterior frontal vein (o) middle temporal vein (p) posterior temporal vein (q) anterior temporal vein (r) posterior frontal vein (s) anterior frontal vein (t) middle temporal vein (u) posterior temporal vein (v) anterior temporal vein (w) posterior frontal vein (x) anterior frontal vein (y) middle temporal vein (z) posterior temporal vein.

Two or more frontal veins was the most common finding: a single vein occurred in only 13 cases. The diameter of the widest frontal vein exceeded 2 mm in all but four cases. Generally (30 patients) a frontal vein on each side continued down to the medial canthus where it joined the ipsilateral supraorbital vein to form the angular vein, which continued downwards as the anterior facial vein. The supraorbital vein originates lateral to the orbit where it anastomoses with the extracranial temporal veins and passes medially along the superior orbital ridge between the frontal muscle and the *musculus corrugator supercilii*. It then perforates the orbicular muscle to reach the frontal vein at the medial canthus of the eye. In 105 orbits the supraorbital veins could be observed. In two cases no supraorbital vein could be demonstrated on one side in spite of an adequate filling of the veins in the vicinity. In 30 orbits the vein was filled only from the medial canthus to the supraorbital incisure—probably a valve existed lateral to this incisure in these cases. In 40 orbits a frontal vein anastomosed with the supraorbital vein near the supraorbital incisure. In the vast majority of cases wide collateral veins connect the two halves of the face in the forehead as well as at the root of the nose. However in a few cases these communications were so narrow that the passage of contrast medium to the contralateral orbit was impaired.

Superior ophthalmic vein. The origin of the superior ophthalmic vein could be evaluated in 107 orbits. The minimum diameters of the supraorbital and the angular tributaries were measured in the view where they were best demon-

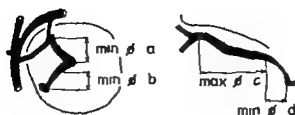


Fig 6 Bilateral duplication of the superior ophthalmic vein. On the left side only the middle part of the vein is double lumen on the right and the double segments include the anterior as well as the middle part of the vein. Bilateral filling of inferior ophthalmic vein. a) Ap projection b) Sinusoidal projection

b

strated and the cases then classified (Fig 3). In half of the cases the angular tributary was the widest and in one third the supraorbital tributary was wider (Fig 4). The course of the superior ophthalmic vein in this material corresponded to previous reports on orbital anatomy and phlebography (Fig 5). Essentially the same nomenclature as that of HANAFEE *et al* (1968) is used by the present author (Fig 5). The anterior segment of the superior ophthalmic vein crosses under the superior rectus muscle and runs a course directed laterally backwards. The middle segment commences at the lateral inflexion point where the vein reaches the lateral border of the superior rectus muscle and then follows the lateral border of that muscle dorsally medially towards the superior orbital fissure. The posterior segment is best observed on a lateral view. It begins where the vein turns downwards to pass through the superior orbital fissure and ends where the vein enters the cavernous sinus.

In one third of the orbits at least a part of the vein was duplicated and in a few cases the veins were paired in their entire course through the orbit (Fig 6).



Measurements during compression

	N (n = 36)	S (n = 17)	N+S (n = 53)
a	30 (11-60)	27 (13-55)	29 (11-60)
b	12 (0.5-20)	13 (0.7-19)	12 (0.5-20)
c	36 (19-56)	34 (18-58)	35 (18-59)
d	18 (12-24)	17 (13-23)	18 (12-24)

Fig. 7. Different diameters of the superior ophthalmic vein during compression. (a) the anterior view the minimum diameter was measured in the superior rectus area () as well as in the posterior segment (b). In the lateral view the maximum diameter of the intraorbital part of the vein (c) as well as the minimum diameter of the posterior segment (d) was measured. Mean values and ranges displayed for the groups N (normal orbit and cavernous sinuses) and S (normal orbit intraorbital expanding lesion) separately as well as for the total series (N+S).

In cases with incomplete duplication this usually occurred around the lateral deflection point (Fig. 13). The duplications were short in almost half of the cases.

Diameters. The diameter of the superior ophthalmic vein was constantly reduced as the vein passed through the supraorbital fissure also in this material. The diameter of the vein was measured directly on the films exposed during compression (Fig. 7). Mean values were calculated separately for the groups N and S (the number of orbits allowing measurement reduced to 36 and 17 respectively as some veins were not suited for measurement mostly because of vein duplication). No differences between the two groups were found. Mean values and ranges for the groups N and S are given separately as well as sum



Fig 8 Marked local widening of the internal part of the superior ophthalmic vein sinus ophthalmicus (→) a) A.p. b) lateral view

marized (Fig 7). The superior ophthalmic vein, after having passed through the superior orbital fissure, in most cases increased in width while descending to the cavernous sinus. A significant widening of the internal part of the vein was present in several cases (Fig 8), probably corresponding to the sinus ophthalmicus described by 19th century anatomists.

Significance of non filling of the superior ophthalmic vein. Without compression the superior ophthalmic vein was demonstrated in 79 out of the 104 orbits adequately examined. Ten out of the remaining 25 in which the vein did not fill with contrast medium proved to have an intraorbital lesion.

During compression, non filling of the vein occurred in only one orbit in a patient with a large sphenoidal ridge meningioma with marked protrusion of the orbital contents. In all other cases adequately examined the superior ophthalmic vein was demonstrated in its entire course or close to the site of an occlusion. Even in a case with a large fistula between the carotid artery and the cavernous sinus the vein on the side of the fistula could be filled (Fig 9). This indicates the efficacy of the technique used and stresses the importance of adequate compression and rapid injection of medium.

The effect of compression on the width of the vein was evaluated separately for the groups N and S (the number of cases reduced to 28 and 16 respectively after exclusion of orbits not examined without compression or where the vein was not filled without compression or was duplicated). No differences could be found between these two groups. Mean values and ranges are given in Fig 10 for the groups separately as well as for the total series of 44 orbits. The mean increase in diameter during compression was about 45 per cent with a range



Fig. 1. Arterio-venous fistula supplied from branches of the external carotid artery. (a) lateral plain gray film, (b) contrast filling of the intracranial veins.

from 0 up to 200 per cent (Fig. 11). The widening may even cause an evident displacement of the vein (Fig. 12).

Differences between left and right orbits in the course of the superior ophthalmic vein were assessed in 17 subjects. Seven of them had normal cavernous sinuses and 10 had an intracellar expanding lesion without signs of obstruction of the flow. In six patients no significant difference existed between the left and the right orbit. Asymmetric duplications of the superior ophthalmic vein without any significant asymmetry in the course of the vein was observed in six cases. In four of these the double segments were unilateral, three of them very short. In two cases different types of duplications of the right and left superior ophthalmic vein were encountered. Significant asymmetry between the two orbits existed in five patients. In one of these it cannot be excluded that an asymmetric injection of contrast medium may have contributed to this difference. In the remaining four patients (two from each of the group A and S) the superior ophthalmic vein was more or less duplicated, in two (Fig. 13) only a very short double segment existed at the lateral deflection point. In several cases the anterior part of the superior ophthalmic vein on one side described an extra loop in the a.p. view (Fig. 14); only one of these was also included in the group of 17 cases used for evaluation of the intrasubject differences.

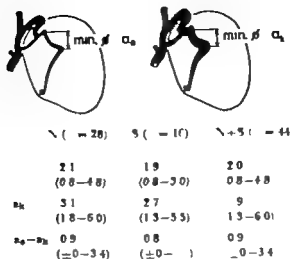


FIG 10 Effect of compression. Only cases with filling of the superior ophthalmic vein after d without compression are included. The minimum diameter of superior ophthalmic vein in superior rectus curve as measured on the p. series from series exposed without () as well as with (x) compression. Mean values and ranges displayed for the groups N (normal orbit and cavernous sinuses) and S (normal orbit intracranial expansion lesion) separately as well as for the total series (N + S).

Discussion

The technique used in this investigation (BRISMA) gives more distension of the facial veins than other techniques. This may explain why the constancy of the double origin of the superior ophthalmic vein described by the classic anatomists and also assessed in this series has not been observed by many previous authors at orbital phlebography. BODER (1953, 1955) mentions that in addition to a superior main branch (the supraorbital tributary) a small accessory inferior branch (the angular tributary) may exist. From his illustrations it is evident however that he sometimes confuses the two tributaries. LOMBARDI & PASSERINI (1968) describe the angular branch as the proximal part of the superior ophthalmic vein. However they state that the first segment was sometimes absent and its place then taken by a superficial vessel that united directly with the next segment. From their illustrations it is evident that this vessel is the supraorbital branch.

Several authors have regarded the angular tributary to the superior ophthalmic vein as the first part of that vein. In the French literature the appearance



Fig. 11 Orbital phlebography without (a) and with compression (b)

of the superior ophthalmic vein in the a p view is classically described as a parallelogram with one side absent. In an a p view angulated 10° from below OFFRET & ARON ROSA (1963) measured the angles of this parallelogram. Their normal values (50° to 60° for the angle between the angular tributary and the first part of the superior ophthalmic vein and 110° for the lateral angle) were questioned by LOWBARD & PASSERINI however as those angles may vary considerably with small changes in projection.

An evident displacement of the superior ophthalmic vein such as is often observed in intraorbital tumors causes few diagnostic problems. The frontal vein approach to orbital phlebography (VARRASIO 1961) allowed a comparison between the veins in the right and left orbits and even small differences in the course of the veins could be disclosed. However in the present material quite large differences in the course of the superior ophthalmic vein normally existed between the right and left orbits. Thus caution must be taken not to diagnose a localized expansive lesion in such cases. The interindividual differences are still larger and thus it is not possible to give normal values for the course of the superior ophthalmic vein.

HANAFY (1972) stresses the importance of not jumping to the conclusion of

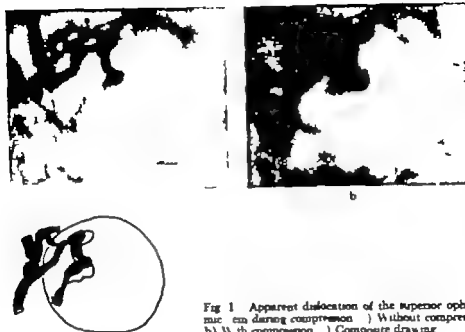


Fig 1 Apparent dislocation of the superior ophthalmic vein during compression a) Without compression b) With compression c) Composite drawing

superior ophthalmic vein obstruction as lack of filling of the posterior aspects of the superior ophthalmic vein may be a purely technical result or may be related to an increased flow phenomenon. When passage of contrast medium to the orbit is not impaired by narrow collateral veins or by compression of these veins and when the external digital compression is effective non filling of the superior ophthalmic vein is a definite pathologic finding if the author's technique of injection is used. This statement is contrary to the opinion expressed previously (HAAFAEE et coll 1968). The rapid injection of contrast medium also causes a distension of the orbital veins. Thus the average diameter of the superior ophthalmic vein in this material exceeds the maximal values for normal variations given by OFFRET & ARON ROSA (1963) and ARON ROSA et coll (1966). The former claimed that the diameter of the superior ophthalmic vein in normal cases did not exceed 2 mm. ARON ROSA et coll increased that limit to 2.5 mm. HAAFAEE et coll reported diameters varying from 1 to 5 mm in normal subjects. They also found that in the same individual one ophthalmic vein could be twice as wide as the other. The amount of contrast medium reaching each orbit is dependent on the injection site on variations in the anatomy of the facial veins and on the efficacy of the applied external compression. Thus the diagnostic significance of differences in width of the right and left superior ophthalmic veins is limited. The high incidence of unilateral varicosity reported by some

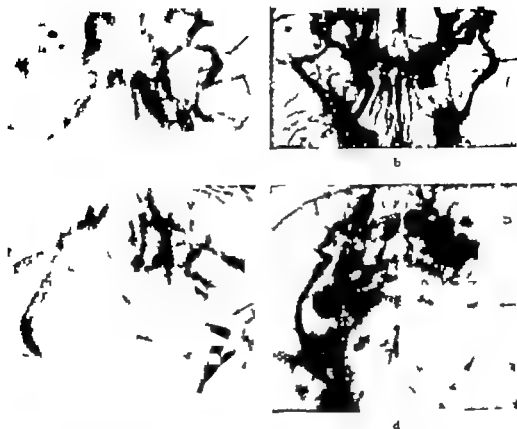


Fig. 13 Two patients with a clinically stable intraorbital disorder demonstrating marked asymmetry of the superior orbital vein. In (c) the patient manifested unilateral displacement of the superior orbital vein as found (→) in (c). For patient (p) and vein (w) in (d) see corresponding axial view.

authors (ARON, ROSA *et coll.* 1966) may be at least partly due to the use of too narrow limits for the normal variations in width of the vein, possibly in combination with a lateralized injection of contrast medium.

The technique used in orbital phlebography, whether performed via angular or frontal vein injection, or via injection through the inferior petrosal sinus, always induces a local increase in venous pressure which may disturb the normal flow. Manual or mechanical compression manoeuvres increase this disturbance. Thus valid conclusion concerning the dynamics of flow in the intraorbital veins can hardly be based upon orbital phlebography.

Whether the flow in the superior orbital vein is directed from the facial veins to the cavernous sinus or vice versa has been discussed for a long time. SEEFMAN considered that the superior orbital vein acted as an emissary vein

for the cavernous sinus. He based this opinion on the observation that the superior ophthalmic vein had a much smaller diameter at the cavernous sinus than at its facial end. He considered that normally the orbit drained mainly towards the facial veins but that a smaller amount of blood also passed to the cavernous sinus. When pressure increased in the sinus blood was thought to pass from the sinus via the orbit towards the facial veins. A previous prevalent conception of a flow from the facial veins towards the cavernous sinus was based on the fact that the intraorbital veins join at an acute angle directed towards the cavernous sinus. SESEMAN stated, however, that the rich network of anastomotic veins in the orbit reduced the weight of that argument.

MERZEL (1874) not having been able to confirm a narrowing of the internal part of the superior ophthalmic vein questioned the opinion of SESEMAN. DONDEES (1871) pleaded that the blood from the orbit normally flowed through the cavernous sinus to the internal jugular vein. As no valves exist in the veins of the orbit DONDEES suggested that the direction of flow could be reversed in cases of flow impairment. GURWITSCH demonstrated as did SESEMAN previously that the lumen of the superior ophthalmic vein was constantly reduced as the vein passed through the superior orbital fissure. He supposed however that not only the orbital blood, but also some blood from the facial veins drained through the orbit to the cavernous sinus.

HANAFEE (HANAFEE et coll 1965 1968 HANAFEE 1972) has successively changed opinion. In the first report (1965) on orbital phlebography it was stated that the superior ophthalmic vein drained directly into the cavernous sinus in the following (1968) that the superior ophthalmic vein drained posteriorly into the cavernous sinus through the superior orbital fissure as well as anteriorly into the angular vein and in a more recent report (1972) that the flow in the superior ophthalmic vein generally is in the postero-anterior direction.

Based on carotid angiography with filling of the superior ophthalmic vein most authors at present consider that the flow normally is directed towards the cavernous sinus but that a reverse flow may occur in cases with intracranial disorders (HACKE & PORRERO 1969 TOWNOW & PISCOL 1971 TOWNOW 1972). Preliminary results of the present author coincide with these opinions.

SUMMARY

The anatomy of the superior ophthalmic vein and its anastomosis in material of orbital phlebography are described. The diameter of the vein varied within a wide range in apparently normal subjects. No complete symmetry existed between the two orbits. Care must thus be taken not to overdiagnose intraorbital expansion, lesions from chronic sinusitis.

ZUSAMMENFASSUNG

Die Anatomie der oberen Orbitalvene und deren Variationen werden bei einem Material an Orbitalphlebographien beschrieben. Der Diameter der Vene weist eine grosse Variationsbreite bei offenbar normalen Personen auf. Es bestand keine vollständige Symmetrie zwischen den beiden Augenhöhlen. Man muss vorsichtig sein, nicht intraorbitale expandierende Schäden aus Asymmetrien der Venen zu überdiagnostizieren.

RÉSUMÉ

Description de l'anatomie de la veine ophtalmique supérieure et de ses variations sur une série de phlébographies orbitaires. Le diamètre de cette veine est très variable chez des sujets apparemment normaux. Il n'y a pas de symétrie absolue entre les deux orbites. Il faut donc éviter de ne pas porter trop souvent le diagnostic d'lésion expansive intraorbitaire sur la base d'asymétries veineuses.

REFERENCES

- ARON ROSE D. OFFRET G. RAMEL A. METZGER J. AARON C. et ROSE A. La phlébographie orbitaire. Bull. Soc. Ophtal. Fr. (1967) 5 pp.
- RAMEL A. et METZGER J. La phlébographie orbitaire I. L'exploration neuroradiologique en ophtalmologie. p. 136. Edité par P. Guilloit, H. Samur et R. Sedan. Masson et Cie. Paris 1966.
- BOLDREY CH. Premiers résultats de phlébographie orbitaire. Thèse Montpellier 1953.
- La place du phlébogramme orbitaire dans le diagnostic des tumeurs de l'orbite. Arch. Ophtal. (Paris) 15 (1955) 597.
- BRISMAZ J. Orbital phlebography. I. Technique. Acta radiol. Diagnosis 15 (1974) 369.
- DONDERS F. C. Über die Struktur der Augen bei expiratorischem Blutandrang. Albrecht Graefes Arch. Ophtal. 17 (1871) 85.
- GURWITZ M. Über die Anastomosen zwischen den Gesicht- und Orbitalvenen. Albrecht Graefes Arch. Ophtal. 29 (1883) 31.
- HACKER H. und FORRERO M. Darstellung und Bedeutung der Venophthalmica im Karotis-Angiogramm. Fortschr. Röntgenstr. 110 (1969) 656.
- HANAUER W. Orbital enography. Radiol. Clin. N. Amer. 10 (1972) 63.
- ROSE L. M., WILMER W. and WILSON G. H. Venography of the cavernous sinus orbital veins and basal menous plexus. Radiology 84 (1965) 751.
- SHULTZ P. and DARTON G. Orbital enography. Amer. J. Roentgenol. 104 (1968) 29.
- LOWMAN G. and JASPERIN A. Venography of the orbit: technique and anatomy. Brit. J. Radiol. 41 (1968) 282.
- MEYER F. J. Handbuch der gesamten Augenheilkunde. III 107. Herausgegeben von Graefe und Saemisch. Leipzig 1874.
- OFFRET G. et ARON ROSE D. Le phlébogramme orbitaire. Arch. Ophtal. (Paris) 25 (1963) 85.
- SERVAZ F. Die Orbitalvenen des Menschen und ihr Zusammenhang mit den oberflächlichen Venen des Kopfes. Arch. Anat. Physiol. (1869) 154.
- TORROW K. Beitrag zur angiographischen Diagnostik der blinden Thrombose des Sinus cavernosus. Radiologie 11 (1971) 40.
- and FISCHER K. The evaluation of the superior ophtalmic vein on the carotid angiogram. Neuroradiology (1971) 30.
- VARRON A. A new method for demonstrating ophtalmic veins, facial veins and superficial venous system of the head. (In Greek.) Arch. ophtal. Heteroborellad. 12 (1961) 223.

COMPUTER ASSISTED TOMOGRAPHY OF INTRACRANIAL CSF CIRCULATION USING A WATER-SOLUBLE CONTRAST MEDIUM

TORONY GREITZ and TOMAS HINDMARSH

By the introduction of isotope cisternography (DI CHIRO 1964) a new tool was provided for the investigation of the circulation of the cerebrospinal fluid (CSF). To-day this method is regarded as indispensable in the examination of patients with disturbances of CSF dynamics especially those with communicating hydrocephalus. However isotope cisternography is hampered by certain drawbacks. Passage of the tracer material to the ventricular system is an important sign of pathology but may be difficult to ascertain especially in patients with small ventricles due to the low resolution of isotope scanning methods. Furthermore the ventricles in the lateral view are superimposed on the sylvian fissures and in the a.p. and axial views on the interhemispheric fissure these fissures being main CSF pathways usually contain large amounts of the isotope which may render evaluation of ventricular filling difficult. Another disadvantage of the method is the relatively high radiation doses to the spinal cord (HILDRICH 1968, WAGNER et al. 1970) which significantly restricts the number of examinations that can be made in one and the same patient. Computer assisted axial tomography (HOUNSFIELD 1973, AMBROSE 1973) in the following referred to as

Submitted for publication 12 March 1974.

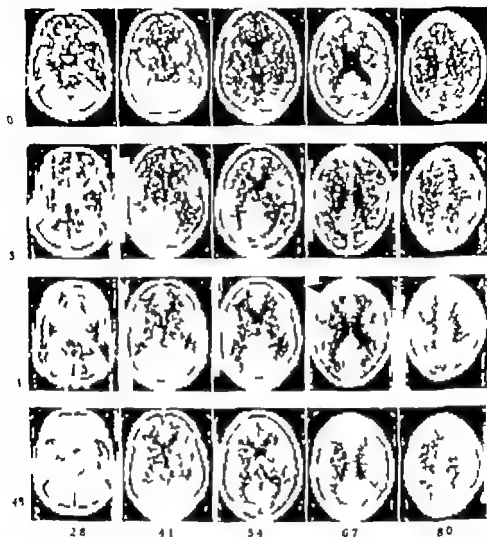


Fig. 1. Normal case. Intracranial distribution of metrizamide follow up myelography. 1. the lumbar roots. 2. time intervals (h) as indicated by figures to the left. 3. or figures indicate tomographic level in cm. 4. external meatus. Sections parallel to the supracaudal-midline. After 3 hours contrast medium in the cisterns of the posterior fossa in the quadrigeminal and ambient cisterns in the suprasellar cisterns as well as in the lateral and interhemispheric fissures and beginning to appear in the sulci over the convexity. At medium is present in the ventricular system. After 24 hours maximum concentration over the convexity and in the interhemispheric fissure. Contrast medium still discernible parasagittally after 48 hours.

CT scanning was used by HINDMARSH *et al.* (to be published) to map out the routes of transport within the intracranial subarachnoid space following myelography with the water soluble contrast medium metrizamide (Nyegard Oslo)

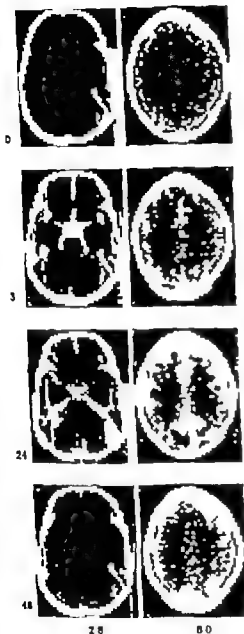


Fig 2 Same case figures to the left indicate time intervals (h) and lower figures section levels in cm. Only attenuation coefficients above 30 are represented in the left row (basal section) and coefficients above 25 in the right row. The time difference between clearance of the suprasellar cisterns and clearance of the CSF spaces in the superior part of the left hemispheric fissure is demonstrated.

This non ionic medium is well tolerated when applied to the subarachnoid cisterns (SALVESEN 1973 GONSETTE 1973 GREPE & WIDEN 1973 GREPE 1975). The sensitivity of computer assisted tomography in detecting differences

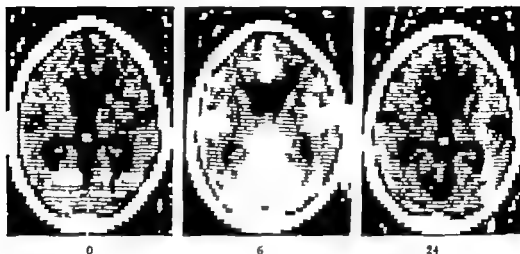


FIG. 3 A slight filling of the lateral ventricles and the third ventricle in the 6 hour scan

in tissue attenuation (absorption) is about 100 times that of conventional radiography. An iodine solution containing only 1–2 mg/ml has a higher attenuation than brain tissue and hence even a lower concentration has an attenuation high enough to be differentiated from normal CSF.

Material and Methods Eight patients without signs or symptoms of impediment of the intracranial CSF circulation were examined with computer assisted axial tomography before and at varying intervals after myelography of the thoracic and cervical regions usually at 3, 6, 24 and 48 hours. These patients were considered to be normal with respect to the intracranial CSF circulation although three of them had a partial block of the CSF pathways in the spinal canal. In addition one examination was made in a patient who had clinical signs of communicating hydrocephalus evidenced by characteristic findings at encephalography and by an intraventricular isotope uptake at cisternography. For the purpose of uniformity the contrast medium was brought up to the cervical region also in this patient. The amount of metrizamide administered varied between 8 and 18 ml of a solution containing 170, 200 or 300 mg I/ml corresponding to a mean dose of 2.75 g I (range 1.6 to 3.9 g I).

The tomographic sections were 1.3 cm thick and parallel to the supraorbitomental line. All patients were scanned in the supine horizontal position but the head-end of the bed was raised about 15 to 20° between scanning procedures and for 24 hours after the injection. Between 24 and 48 hours no positional restrictions were imposed upon the patient.

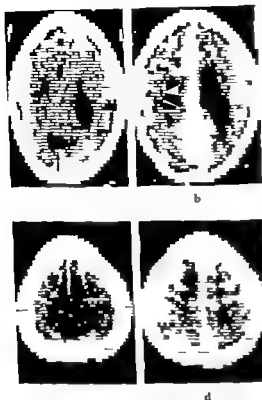


Fig 4 a) Patient with porencephalic cysts (→) b) These are filled with contrast medium which proves their communication with the subarachnoid space c) Normal case The sulci over the convexity not seen before injection () but filled with contrast medium 74 hours after injection (d)

Results

In all patients the contrast medium filled the cisterna magna as well as the ambient and quadrigeminal cisterns. In the four patients from the normal group who were examined 1 to 3 hours after myelography the medium was seen to have spread to the basal parts of the interhemispheric and sylvian fissures. Filling of the ambient and quadrigeminal cisterns occurred at the same time (Fig 1). At scanning after 24 hours the contrast medium had reached the superior parts of the interhemispheric fissure and was also observed in cortical sulci over the convexity. Although most of the sulci contained contrast medium the maximum concentration seemed to occur in the parietal parasagittal region corresponding to the convexity peak normally seen in isotope cisternography (Fig 2). After 48 hours contrast medium was usually still discernible parasagittally but in a lower concentration. In two patients in the normal group a slight intraventricular filling was evident, in one case at the 6 hour examination and in the other at the 24 hour examination but in none after 48 hours (Fig 3).

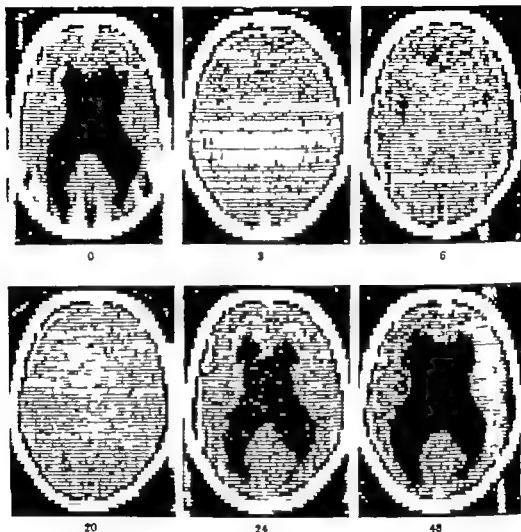


Fig 5 Communicating hydrocephalus. Scans at the same level (6.7 cm) taken before as well as 3, 6, 20, 24 and 48 hours after the injection. Successive uptake and clearance of the contrast medium within the lateral ventricles. A slight increase in the size of the ventricles is seen after 3 and 24 hours (the patient complained of headache at the same occasion). In these early scans narrow zones of retained low attenuation is seen adjacent to the ventricles which may reflect absorption of CSF not containing contrast medium.

In another patient porencephalic cysts were filled with contrast medium and hence communicating with the subarachnoid space (Fig 4a).

In the patient with communicating hydrocephalus contrast medium filled the cisterna magna but was not observed in the supratentorial subarachnoid cisterns.

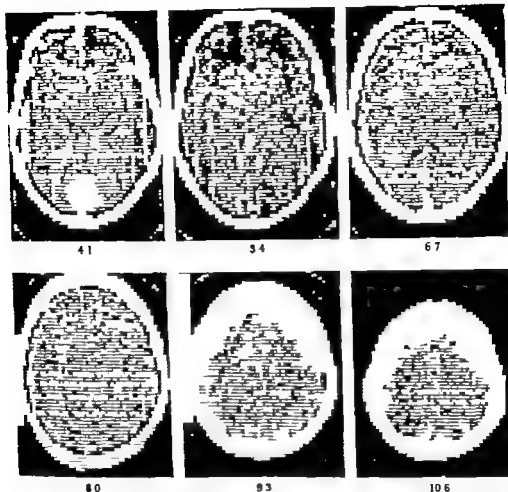
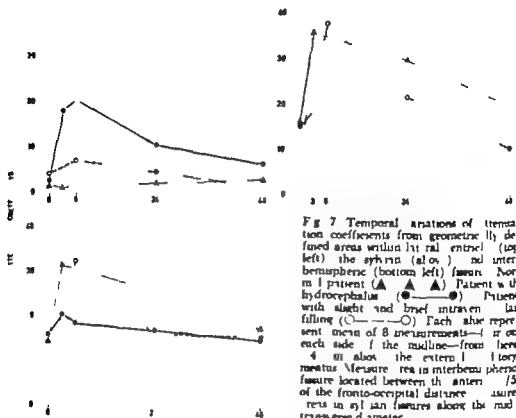


Fig 6 Same case as in Fig 5 Spatial distribution 3 hours after injection of contrast medium. Marked filling of the cisterna magna and ambient cisterns slight filling of the supratentorial extracerebral subarachnoid spaces usually of the sulci in the interhemispheric fissure and over the convexity

and sulci to any appreciable extent (Figs 5-6). Instead 15 hours after the injection contrast medium had passed to the ventricular system and at 3 hours after injection the attenuation coefficients of the CSF within the ventricles increased to a value higher than that of brain tissue. Fig 7 demonstrates the relative variations in attenuation of the CSF within the lateral ventricles, the sylvian and interhemispheric fissures as a function of time when measured in geometrically defined areas of these spaces. An interesting feature was the ap



presence of a thin rim (estimated thickness about 5 mm) adjacent to the ventricular system with a lower attenuation coefficient than the surrounding brain tissue.

Discussion

Although the image obtained by computerized tomography is built up by rather large elements each of which corresponds to a column with a height equivalent to the thickness of the examined slice i.e. 13 mm and a transverse section area of about 3 mm \times 3 mm this method is still far superior to isotope scanning with regard to resolution. Contrary to the situation with isotope scanning techniques and with conventional radiography the information obtained from any given volume within the tomographic slice is not influenced by physical characteristics of tissues outside the slice. The accuracy of CT scanning allows comprehensive mapping of the pathways of tracer transport within the subarachnoid space. Even details such as filling of individual cisterns and sulci

may be discerned (Fig 4 b). This should permit a more complete and detailed analysis of the various pathways and might possibly lead to new concepts of flow patterns in the normal and pathologic CSF circulation. The results obtained in normal individuals in this preliminary investigation suggest that the CSF to a larger extent than has so far been appreciated may take a posterior route over the quadrigeminal plate, in addition to the generally accepted main pathways via the sylvian and interhemispheric fissures.

The run of low attenuation seen adjacent to the ventricles in a hydrocephalic patient may reflect a stage in the process of CSF absorption: the CSF which has a low attenuation producing this effect when absorbed from the lateral ventricles. This absorption was possibly accelerated by an acute increase of hydrocephalus as evidenced from the early scans in this patient (Fig 5).

One objection to the use of a water soluble contrast medium as a tracer of CSF circulation would be its character as a non physiologic agent. However this is also true of other substances used for cisternography, such as RIHSA and Ytterbium DTPA. Furthermore neither of these is capable of revealing all the various phases of events related to the absorption of water. Metrizamide has no protein binding capacity (SALZESEN et coll. 1973). Its high density may prove to be a significant drawback for tracer purposes as it leads to layer formation and makes the transport with the CSF circulation dependent partly on gravity. In all patients included in this investigation the contrast medium was brought up to the cervical area by gravity under fluoroscopic control.

However to evaluate the potential of water soluble contrast media as indicators of CSF flow for use routinely in cisternography by lumbar puncture the possible influence of physical factors on the spread and transport of the medium in the subarachnoid space must be established.

The attenuation coefficients (as read on the computer print-outs) in regions of the subarachnoid space containing contrast medium in most of the cases corresponded to an iodine concentration of 1–2 mg/ml. The density of a pure metrizamide solution of this concentration would be less than 1.005 g/ml, i.e. lower than that of the normal CSF which varies between 1.005 and 1.009 g/ml (SOMDERMAN & BOERWER 1950). Hence it should be possible to use a comparatively large volume of a metrizamide solution with a density close to that of the CSF in order to ensure a rapid and reliable transport of the medium to the intracranial subarachnoid space. The time table and the pathways of intracranial transport of the medium may then be evaluated taking the level of the cervico-cranial junction as a starting point. Work along this line is being pursued at present.

By the introduction of computerized tomography it seems as though water soluble contrast media, long used as indicators in the investigation of hemo-

dynamics deserve to be considered also for the purpose of investigating the CSF circulation

Acknowledgements

This investigation was supported by grants from the Swedish Cancer Society, Knut och Alice Wallenbergs Stiftelse and Carl Bert i Nathorsts Vetenskapliga och Allmansynliga Stiftelser

SUMMARY

A method is proposed to examine the intracranial CSF circulation by computer assisted axial tomography using a low concentration of a water soluble contrast medium. Preliminary results are reported in patients with and without disturbances of the CSF circulation.

ZUSAMMENFASSUNG

Es wird eine Methode vorgeschlagen die intrakranielle CSF Zirkulation mittels computerisierter Tomographie unter Anwendung eines wasser löslichen Kontrast Mittels zu untersuchen. Es wird über vorläufige Ergebnisse bei Patienten mit und ohne Störungen der CSF Zirkulation berichtet.

RÉSUMÉ

Les auteurs proposent une méthode d'examen de la circulation du liquide cerebrospinal par tomographie traitée par ordinateur en utilisant une faible concentration de moyen de contraste hydrosoluble. Ils présentent les résultats préliminaires obtenus sur des patients avec et sans perturbation de la circulation du liquide cerebrospinal.

REFERENCES

- ANDERSSON J. Computerized transverse scanning (tomography). Part II. Clinical application. Brit J Radiol 46 (1973) 1023
- DE CROMBIE G. New radiographic and isotopic procedures in neurological diagnosis. J Amer med Ass 188 (1964) 324
- GOSSETT E. F. Metrizamide as contrast medium for myelography and ventriculography. Preliminary clinical experiences. Acta radiol (1973) Suppl No 335 p 346
- GREITZ T. Cisternography with the non ionic water soluble contrast medium metrizamide. A preliminary report. To be published in Acta radiol. Diagnosis 16 (1975)
- and WROTH L. Neurotoxic effect of intracranial subarachnoid application of Metrizamide and meglumine iocarmate. An experimental investigation in dogs in neurolept analgesia. Acta radiol (1973) Suppl No 335 p 107
- — Effects of internal application of metrizamide. An experimental investigation in dogs in N_2O analgesia with and without Halothane. Acta radiol (1973) Suppl No 335 p 119

- HILNITCH T E Radiation dose in isotope encephalography *Lancet* 2 (1968) 573
- HINDMARSH T GREPE A and WIDFELT L Metrizamide phenothiazine interaction: Report of a case with seizures following myelography To be published in *Acta radiol Diagnost* 16 (1975)
- HOUNSFIELD G N Computerized transverse axial scanning (tomography) Part 1 Description of system *Brit J Radiol* 46 (1973) 1016
- SALVESEN M Suboccipital injection of metrizamide to anesthetized and unanesthetized rabbits *Acta radiol* (1973) Suppl No 335 p 93
- and FREY K Protein binding of metrizamide and the effect on serum enzymes *Acta radiol* (1973) Suppl No 335 p 247
- SCUNDERMAN F W and BOWEN F Normal values in clinical medicine Saunders Philadelphia 1950 p 315
- WAGNER H N HOSAIN F DELANEY F H and SOM P A new radiopharmaceutical for cisternography *Radiology* 95 (1970) 121

EXTERNAL FACTORS AFFECTING PARASTERNAL SCINTIGRAPHY WITH TECHNETIUM 99m SULFIDE COLLOID

An investigation in the rabbit

L. R. GORANSON and K. JONSSON

The parasternal lymph nodes are of considerable clinical importance forming as they do one of the primary areas for lymph drainage from the breast (ROUVIERE 1932) they are perhaps best examined by parasternal scintigraphy usually with Au colloid injected on each side of the xiphoid process or behind it in the midline (DIETHELM *et coll* 1967 ROSSI & FERRI 1966 SCHYNA 1966 SCIENZA *et coll* 1966 ROSSI *et coll* 1968 MICHAELOV *et coll* 1968 KAZEM *et coll* 1968 1969 SEIFERT & BETZNER 1970 MEYER BURG & WILHELM 1971 GROS *et coll* 1969 1972)

A similar technique with ^{99m}Tc -sulfide colloid has already been described (GORANSON & JONSSON 1974) The purpose of the present investigation was to determine whether certain external factors influence parasternal scintigraphy i.e. (1) the colloid itself blocking the parasternal lymphatics for consecutive examinations (2) incision and inflammatory reaction of the chest wall influ

Submitted for publication 21 June 1973

Table
Procedures in the examinations

Procedures	% of animals	Remarks	
Repeat examinations			
< 6 days	8		
8 days	1		
34 days or over	6		
Total	15		
Incision of the chest		Postop infection	No postop infection
sterile procedure	3	2	1
non sterile procedure	9	7	2
Total	12	9	3
Injection of contrast media into the peritoneal cavity		Scintigraphy after 3 hours	Scintigraphy after 4 hours
Iodized oil emulsion	7	7	
Thorotrast	4	1	3
Injection of blood into the peritoneal cavity		Scintigraphy 4 hours after inj	
Heparinized blood	4		
Non heparinized blood	5	Scintigraphy 4 hours after inj	

encing or blocking the uptake of the tracer substance and (3) the injection of contrast media or blood into the peritoneal cavity with subsequent filling of the parasternal lymph vessels (COURTICE et coll 1953 HARRIS et coll 1944) causing blocking of the uptake of the tracer

Material and Methods Rabbits weighing between 1.5 and 3 kg were anaesthetised with intravenous pentobarbitone sodium. The $Tc^{99m}S$ colloid for the experiments was prepared by the method of PERSSON & NÄVERSTEN (1970) and was concentrated to a volume of one ml with an activity of 500 Ci. Two hundred IU hyaluronidase were dissolved in the colloid half of the solution being injected sub or intracutaneously on each side of the upper pre-c. The animals were placed supine under a pin hole collimator of a gamma camera (Nuclear Chicago Pho Gamma III) and the uptake in the parasternal lymphatics was followed for 15 to 60 minutes.

The different procedures are illustrated in the Table. The examination was

repeated at 0 days in 8 animals and at 8 days in one animal at 34 days in 4 animals and at 48 and 71 days respectively in two animals.

The left chest wall was shaved and an incision made following the subcutaneous injection of mepivacaine (Carbocain 1%) in 12 animals. A 3 cm incision was made in close relation to one of the nipples; the subcutaneous tissue was excised and the wound sutured; the incision was made in 9 animals under non-sterile and in 3 animals under fully sterile conditions. Scintigraphy was performed one week after the operation. Two ml of an iodized oil emulsion were injected into the peritoneal cavity in 7 rabbits immediately below the ventral portion of the diaphragm and 2 ml Thorotrast were injected in 4 rabbits at the same site. Lateral and oblique films of the chest were obtained 3 hours after injection except in 3 of those injected with Thorotrast when the roentgenograms were taken at 24 hours. Paraxillary lymph vessels and lymph nodes in the superior mediastinum were demonstrated in all the animals. Scintigraphy was performed shortly after radiography.

Twenty ml of unprepared rabbit blood were injected intraperitoneally in 5 animals and 20 ml of heparinized rabbit blood similarly in 4 animals. The injection of a small amount of (water soluble) Iopaque under fluoroscopic control ensured that the tip of the needle for injecting the blood lay in the free peritoneal cavity. Scintigraphy was performed at four hours in the animals injected with non-heparinized blood and at 24 hours in those injected with heparinized blood. Paraxillary lymph vessels and lymph nodes of the superior mediastinum from animals injected with Thorotrast and heparinized blood were dissected and examined histologically.

Results

An uptake of the tracer was noted in the bilateral groups of lymph nodes in the superior mediastinum in all healthy animals in accordance with previous findings (Goranson & Jonsson 1974).

Consecutive scintigrams did not indicate abnormalities; the second examination always proved to be as good as the first. Nine of the animals with an incision of the left chest wall developed local inflammatory reaction; the wound healed by first intention in 3 animals. The scintigrams were normal in all animals operated upon except one in which no uptake in the left lymph nodes was evident. In 4 of the operated animals the left lymph nodes had a greater uptake of colloid than was usual, indicating an increase in their size.

All the animals that had been examined with the iodized oil emulsion injected into the peritoneal cavity had a normal scintigram. Two of the animals previously injected with Thorotrast, had normal scintigrams. One of these had been

injected three hours before the scintigraphy. No uptake in the mediastinal lymph nodes was noted in one of the animals and uptake in the right axillary lymph nodes was observed in another although not in the mediastinal nodes. No uptake of the colloid was observed in one of the animals injected with heparinized blood in the peritoneal cavity. The remaining animals had normal scintigrams including all those injected with non heparinized blood. The histologic examination of the ventral mediastinal lymph nodes revealed blood and contrast medium in the lymph nodes and vessels proving absorption from the peritoneal cavity. The subsequent histologic examination after Thorotrast revealed inflammatory reaction and oedema in the lymph nodes: these as well as the parasternal lymph vessels contained much contrast medium.

Discussion

The normal variations and the way in which external factors affect the examination must always be known. One of the fundamental demands is that consecutive examinations must be independent of each other. It has been claimed that parasternal scintigraphy with ^{131}I colloid may easily be repeated (HAZEM et coll 1969, MICHAÏLOV et coll 1968, MEYER BURG & WILHELM 1971). The present investigation permitted the same conclusion with ^{99}Tc S colloid. The period of time between the first and the second examinations was chosen at random but for clinical purposes no indication for performing the second examination under 6 days after the first was apparent.

Lymph from the upper part of the abdomen and the chest wall, including the breast is drained to the parasternal lymphatics (ROUVIERE 1932). Mastectomy induces inflammatory reaction and waste products have to be transported from the wound to the parasternal lymph vessels. It has been claimed (ROSLER 1971) that mastectomy may block the parasternal lymph vessels making postoperative parasternal scintigraphy on the operated side less reliable. It is thus impossible to say whether the lack of filling of the parasternal lymph nodes on the operated side is due to metastases or to the operation. Mastectomy including axillary exploration produces gross trauma: this is difficult to simulate in experimental animals. No effort to do so was made in the present series but incision and removal of subcutaneous tissue ought to simulate biopsy of the breast. Extensive infection developed in most of the animals. No blocking of the parasternal lymph flow was noted at scintigraphy except in one animal: it was not clear however whether this absence of uptake was due to inflammation or if technical factors were involved. This phenomenon appeared however in only one of the 12 animals. This indicates that a minor incision for instance for biopsy of a tumour of the breast does not influence parasternal scintigraphy as it is always

made under sterile conditions that cause no such extensive reaction as that observed. In 4 of the 12 animals the left mediastinal lymph nodes had a greater uptake of the colloid than was usual; this may indicate secondary hypertrophy of the lymph nodes due to the inflammation of the chest wall.

Previous investigations have always indicated that the lymphatic absorption from the peritoneal cavity is maintained through lymphatics in the diaphragm to the parasternal lymph vessels (GORANSON *et coll.* 1973, JONSSON & OLIN 1974). These vessels, which drain to upper mediastinal lymph nodes, have been roentgenologically demonstrated with Thorotrast (GORANSON *et coll.*) and iodized oil emulsions (JONSSON & OLIN) injected into the peritoneal cavity in rabbits; the emulsion is rapidly absorbed filling the parasternal lymph vessels within five minutes. No blocking effect of the contrast medium could be demonstrated at scintigraphy three hours after the injection. The investigation has proved that a fine particle oil emulsion is well suited for a combined roentgenologic and scintigraphic examination of the parasternal lymphatics. The absorption was slow with Thorotrast. The mediastinal lymph nodes were first outlined and later the parasternal lymph vessels were filled in a retrograde direction. This indicated that the medium blocked the anastomoses of the lymph nodes and as the absorption continued filling of the lymph vessels was an obstruction phenomenon. The films should be obtained about 24 hours after the injection to obtain high quality representation of the parasternal lymph vessels with Thorotrast. This blocking effect of this medium may be the reason why the mediastinal lymph nodes were not evident in the scintigraphy of two animals; one of these animals had a collateral circulation to axillary lymph nodes, which has not been observed in previous examinations of rabbits (GORANSON & JONSSON).

Blocking of the parasternal lymphatics might be accomplished with blood in the peritoneal cavity. It may be assumed that larger particles cause blocking more readily than small ones; the iodized oil emulsion had a particle size of about 1 μ m (JONSSON & OLIN) while blood corpuscles are around 7 μ m. The Thorotrast particles however are about 0.20 μ m in size (KABISCH 1967) but the oedema of the lymph nodes produced may explain the blocking phenomenon in those cases.

The clinical conclusion to be drawn from the present investigation is that consecutive examinations of the parasternal lymphatics with $^{99}\text{Tc}^{\text{m}}$ S colloid are possible and do not influence each other. Removal of a specimen from the breast for biopsy performed under full sterile conditions fails to influence parasternal scintigraphy while more extensive trauma or inflammation may block the parasternal lymph flow on the ipsilateral side. Particles in the peritoneal cavity may obstruct the lymph flow making the parasternal scintigraphy less reliable for instance after bleeding in the peritoneal cavity during an operation. Tumour

cells in the peritoneal cavity or peritonitis may also influence the parasternal lymph flow.

Acknowledgement

The histologic examinations were performed by Prof N O Berg Department of Pathology, University of Lund whom the authors warmly thank. The investigation was supported by grants from the Swedish Medical Research Council (Proj No B73 14 60 07B) the Faculty of Medicine, University of Lund and the John and Augusta Pers on Foundation for Medical Research.

SUMMARY

The influence of external factors on $^{99}\text{Tc}^m\text{S}$ colloid parasternal scintigraphy in rabbits has been investigated. Consecutive examinations with technetium colloid and incision and biopsy of subcutaneous tissue of the chest wall as well as injection of contrast media and blood into the peritoneal cavity are described and discussed.

ZUSAMMENFASSUNG

Der Einfluss unserer Faktoren auf die parasternale $^{99}\text{Tc}^m\text{S}$ Kolloid Skintigraphie wurde an Kaninchen untersucht. Aufeinanderfolgende Untersuchungen mit Technetium Kolloid und Incision und Biopsie des subkutanen Gewebes der Thoraxwand sowie Injektion von Kontrastmittel und Blut in den Peritonealraum werden beschrieben und diskutiert.

RÉSUMÉ

Les auteurs ont étudié l'influence de facteurs externes sur la scintigraphie parasternale avec un colloïde $^{99}\text{Tc}^m\text{S}$ sur des lapins. Ils décrivent et discutent les examens consécutifs par le colloïde, la technetium et l'incision et la biopsie du tissu sous cutané de la paroi thoracique ainsi que l'injection de moyens de contraste et de sang dans la cavité péritonéale.

REFERENCES

- COLLIER F C, HARROW J and STERNBERG A W. The removal of free red blood cells from the peritoneal cavity of animals. *Am J exp Biol* 31 (1953) 213.
- DETHLEFSEN L, BUCHVALD W, HAAS J P and WOLF R. Erweiterung der Diagnostik von Mammasarkomen mit Hilfe von Isotopen. *J Radiol Électrol* 48 (1967) 677.
- GRON C, VERGUES R, BRICHMAN P et FLEISCHOT M. Place actuelle de la lymphoscintigraphie dans l'exploration du cancer du sein. *J belge Radiol* 55 (1972) 53.
- VERGUES C, SOUTIER J et CHATELAIN D. Lymphoscintigraphie isotopique des chaînes mammaires. *Rev Franç J Radiol Électrol* 50 (1969) 168.
- GOMANOV L R and JORDANOV K. Scintigraphy of the parasternal lymphatic in the rabbit using technetium 99m sulfide colloid. *Acta radiol Diagnost* 15 (1974) 164.

- and OLIN T. Transabdominal roentgenologic and scintigraphic lymphography of the central mediastinum with Thorotrast and ^{99}Tc III colloid in the rabbit. *Acta radiol* Diagnosis 14 (1973) 737
- HAIN P F, MILLER L, ROSSCHITT ROBBINS F S, BAILE W F and WHIFFLE G H. Peritoneal absorption. *J exp Med* 80 (1944) 77
- HAUSER W, ATKINS H L and RICHARDS P. Lymph node scanning with ^{99}Tc sulfur colloid. *Radiology* 92 (1969) 1369
- JONSSON K and OLIN T. The study of iodized oil emulsions for indirect lymphography. *Invest Radiol* 9 (1974) 37
- KARNIC W T. Phagocytosis of colloidal Thorium Dioxide and cobalt oxide by the reticuloendothelial system. *Ann N Y Acad Sci* 145 (1967) 585
- LAZEN I, BRADY L W, CROLL M N, FAUST D J and WOLVERTH O C. The parasternal lymph node scan as a prognostic test in breast carcinoma. *Radiology* 92 (1969) 617
- , ANTONIADIS J, BRADY L W, FAUST D J, CROLL M N and LIGHTFOOT D. Clinical evaluations of lymph node scanning utilizing colloidal gold 198. *Radiology* 90 (1968) 905
- MEYER BURJ J and WOLFFELMI U. Ergebnisse scintigraphischer Untersuchungen parasternaler Lymphknoten mit Au bei Normalpersonen. *Fortschr Röntgenstr* 115 (1971) 54
- NICHAILOV V, MITROV G and VLATKOV C. Indirekte Isotopenlymphographie der parasternalen Lymphknoten mit radioaktivem Gold Au. *Radioecol Radiother (Berl)* 9 (1968) 299
- PERSSON B and NÄVERSTEN Y. Technetium 99m sulfid colloid preparation for scintigraphy of the reticuloendothelial system. *Acta radiol Ther Phys Biol* 9 (1970) 567
- ROSSI R e FERRI O. La visualizzazione della catena mammaria interna con Au 198. (In Italian) *Minerva med* 57 (1966) 1151
- , TRIVELLINI G. La linfoscintigrafia mammaria interna con Au 198. Ricerca sperimentale ed impiego clinico. (In Italian) *Arch ital Chir* 94 (1968) 33
- ROUSTRE H. Anatomie des lymphatiques de l'homme. Masson & Cie Paris 1932
- ROSLER H. Personal communication 1971
- SCHÖNE P. Scintigraphische Darstellung des parasternalen Lymphsystems. *Strahlentherapie* 150 (1966) 504
- , ZIMM WAREL K and BACHER J. Die Scintigraphie des parasternalen Lymphsystems. *Nucl Med Stuttg* 5 (1966) 388
- STOFFT J and BETZOV J. Die indirekt parasternale Lymphscintigraphie beim Mammakarzinom. *Fortschr Röntgenstr* 113 (1970) 457

ANGIOGRAPHIC ABNORMALITIES FOLLOWING PERCUTANEOUS NEEDLE BIOPSY OF THE KIDNEY

R KOHLER and J EDGREN

Percutaneous needle biopsy of the kidney was introduced on a large scale by IVERSEN & BRAUN (1951) and has since won an important position in renal diagnosis. It is used today primarily for investigating inflammatory and degenerative renal changes as well as hypertension. Extraction of a fragment of tissue with a needle, over 2 mm in diameter, leaves a puncture canal that cannot close immediately because of the compact nature of renal tissue. Small blood vessels and renal canals cannot escape damage and sometimes larger vessels may be involved. Even the pelvis of the kidney or surrounding organs and tissues may in isolated cases be affected.

MENO & ELAM (1971) stated percutaneous needle biopsy of the kidney is essentially a controlled ischaemic injury. Traumatic renal lesions may be examined with great accuracy by nephroangiography (OLSSON & LUNDEQUIST 1963, ELKIN *et al.* 1966, HALPERN 1969). This method, which gives both morphologic and functional information on renal changes, has been used in analysing the consequences of renal biopsy. Intrarenal arteriovenous fistulas are roentgenologically impressive and were the first biopsy-induced changes to attract angiographic interest. Close on 70 cases have been reported since the beginning of the 1960s, of which LUNDSTROM (1972) is responsible for more

than a quarter of 22 cases. Important publications on angiographic findings following biopsy in experimental animals appeared in the period 1969—1971 (SWEET et coll 1969 MÜLLER et coll 1969 DITSCHERLEIN 1969 and EKLUND 1970 1971).

The interval between biopsy and angiography for the cases of human arteriovenous fistulas reported usually ranged from a few days to several months. The angiography finding immediately after percutaneous kidney biopsy was described by MEYER & ELKIN and by LUNDSTROM in his monograph of 140 cases. A broad angiographic report on the complications of kidney biopsy could not be found in the literature when this investigation was commenced in 1970.

It was decided to perform angiography 2 to 5 days after the biopsy on the grounds that the possible primary signs would have disappeared and only more marked and therefore more important changes would be expected. This timing of the angiographies proved subsequently to fill the gap between those described by other workers and undertaken immediately after the biopsy and the usually later controls or the angiographies that had revealed arteriovenous fistulas.

Methods and Material. Fifty nephroangiographies were performed in 48 cases in a 14 month period of 1970—1972. Two cases were examined on two separate occasions. Five angiographic investigations were performed aortally, the others selectively, the latter being made in over half the cases in at least two projections. The angiographies represented only about a half the biopsies carried out during the same period. The patients were subjected to angiography if medical interest in the examination existed in connection with their condition or was not prevented by their negative attitude.

The biopsies were performed with the patient prone usually by the same operator with a Silverman-Goldman needle. Before the puncture films were obtained of the kidney during inspiration and expiration with a measuring pen of metal positioned within the field. Poor definition was improved by the injection of urographic contrast medium. The puncture should as far as possible be directed at the lower lateral cortical area of the kidney which provides good accuracy of aim even despite any respiratory displacement of the organ. Renal trauma was always observed in the series.

Ninety-two per cent of the examinations were performed within four days of the biopsy and 52 per cent two days after biopsy, the other examinations being made within a week. Nine patients had slight discomfort and two had marked pain in the renal region after the biopsy. Ten entries appeared in the case reports on microscopic haematuria following the puncture. The commonest histologic findings consisted of different forms of glomerular nephritis, that is in 26 cases. Interstitial nephritis was encountered in 5 cases. Ten cases displayed various types of renal disease, no evidence of abnormality was revealed by biopsy in 7 cases.



Fig 1 Case 1. Selective nephroangiogram the day after biopsy. a) Small extravasation of contrast medium at the biopsy site. Haematoma like soft tissue mass along the lateral contour of the lower pole of the kidney (\rightarrow). b) Scarring from the biopsy site to the kidney surface probably representing the needle track.

Results

No changes in the angiographies were evident in 19 of the 50 examinations but intrarenal leakage of contrast medium from the biopsy site was observed on ten occasions. Peripheral cortical ischaemic defects surrounding the puncture site occurred 12 times and arteriovenous fistulas developed in 9 examinations. A combination of changes was frequent: the cases for these statistics were classified according to the most prominent sign. A combination of leakage and an ischaemic zone was for instance not uncommon. Seven angiographies with abnormalities revealed a haematoma like soft tissue mass along the kidney contour around the puncture site. Multiple arteries were present in 10 cases sometimes masking the region considerably.

Haemorrhage has been one of the serious complications reported in the literature. The principal cause of death in many of the 32 cases ending fatally in connection with biopsy was massive haemorrhage (DITSCHERLIZIN). The same



Fig. 1. Case 1. 7 days after second biopsy read 3 days after the first. a) Small extravasation 10 mm medially from that of Fig. 1. b) Triangular cortical defect resembling haematoma at the first puncture site. c) Oblique. Small extravasation, the needle track and the biopsy site.

The author who collected 15 135 cases from the literature and calculated that the incidence of perirenal haematoma following biopsy was 0.56 per cent. Sixteen cases with a small subcapsular or perirenal haematoma were reported by ZACHARIAS & COLL (1968) in a series of 29 cases of disease of the urinary tract operated upon within 1 to 2 weeks of the biopsy; a large haematoma was evident in 4 cases.

MENO & LILJA established extravasation of contrast medium into the needle track in 17 out of 18 cases at angiography immediately following biopsy as well as perirenal extravasation in 6 cases. LUNDSTRÖM observed leakage of medium in 102 of his 140 cases during a similar period.

Contrast medium leakage occurred intrarenally in all the present 10 examinations. Changes were evident within the cortical region 5 to 10 mm from the renal contour. The leakage began to appear at the beginning of the arterial phase in the form of a 1 to 10 mm accumulation of contrast medium which usually persisted long into the parenchymal phase of the angiography. Two of the 10 cases had a soft tissue mass in association with the renal outline around the puncture site.



Fig 3 Case 2 Selective nephroangiography 2 days after biopsy. Double renal arteries. a) Contrast medium leakage from dorsal artery. b) Small extravasation from the larger ventral artery. Small spot of medium immediately lateral to the extravasation in (a).

Case 1 Woman aged 20 with a normal biopsy. No immediate biopsy signs but selective nephroangiography the next day revealed a small leakage of contrast medium into the lower lateral part of the cortex and a narrow defect running towards the surface this latter probably represented the needle track (Fig 1). In addition, no mass was visible along the lower lateral renal outline. Repeat biopsy was performed 10 days later to obtain better preparation followed after another two days again by selective nephroangiography. The earlier defect persisted, was slightly wider than before and resembled a peripheral ischaemic defect. The lower pole of the kidney contained further small accumulation of contrast medium surrounded by a translucent zone (Fig 2).

Case 2 Woman aged 22 with histologic evidence of interstitial nephritis was examined by selective nephroangiography 10 days after biopsy with no abnormal signs. The kidney was supplied by two arteries; an extravasation of contrast medium measuring 3 mm \times 10 mm was present in the region of the lower artery (Fig 3 a). With a small spot of medium immediately laterally to the extravasation evident on examination of the larger upper artery (Fig 3 b).



Fig. 4



Fig. 5

FIG. 4. Case 3. Selective nephroangiography 4 days after biopsy. Triangular ischaemic area in the cortex of the intermediate part of the kidney. The small extravasation at the apex of the triangle.

FIG. 5. Case 4. Selective nephroangiography 2 days after biopsy. Severe generalized pruning of the peripheral vessel. Cortical haemic defects in lower pole of kidney. Soft tissue masses evident around the puncture site along the renal contour.

Biopsy in dogs and rabbits has revealed signs of arterial spasm, extrarenal leakage of contrast medium, linear defects suggestive of infarction and arteriovenous fistulas. No wedge-shaped cortical defects such as those in the material of LUNDSTROM and the present series were evident.

Only two investigations into cortical defects in human subjects have been unearthed. MENDO & ELLEN observed small peripheral cortical defects in five of their 18 cases of nephroangiographies immediately following biopsy, but they provided no illustrations. LUNDSTROM detected in corresponding examinations in 21 of his 140 cases a lesion characterized by interruption of one or two interlobular arteries and—peripheral to this—a triangular nephrographic defect. The defect reached the kidney surface and was always small.

The present authors were unable to discover any signs of angiospasm in their material. A peripheral ischaemic defect was evident in 12 of the 50 angiographies. The finding confirmed the work of LUNDSTROM. The defect was often accompanied by a small extravasation of contrast medium. It was sometimes distinct and clearly demarcated.



Fig. 6 Case 5 Selective nephroangiography 3 days after biopsy a) Early contrast filling from peripheral fistula in the intermediate part of kidney b) Oblique slightly levitated capsular arteries probably due to small haematoma

Case 3 Woman aged 27 with a diagnosis at biopsy of glomerular nephritis selective nephroangiography undertaken four days later was followed by no abnormalities. A triangular cortical defect with base and sides of about 10 mm had already appeared in the arterial phase (Fig. 4).

Case 4 Woman aged 33 with a diagnosis at biopsy of membranous nephropathy and in whom selective nephroangiography two days after the puncture revealed no abnormality. The renal arteries ran an irregular course. A triangular irregular cortical defect of slightly serrated contour measuring about 15 mm \times 15 mm \times 10 mm lay in the lower pole of the kidney (Fig. 5). A mass as evident around the puncture site running along the renal contour.

The first angiographically demonstrated arteriovenous fistulas caused by needle biopsy of the kidney were reported in 1962 by BOJSEN & KOHLER and FERNSTROM & LINDBLOM. BENNETT & WEINER (1963) described 9 cases from a material comprising 58 needle biopsies. Seven arteriovenous fistulas nephroangiographically verified were analysed by EKLUND & LINDBLOM (1971); the nephroangiographies were performed after 48 needle biopsies. These and the previously mentioned 22 cases described by LINDBLOM are supported in the literature by only one or more cases per author. Twelve of LINDBLOM's cases



FIG. 7 (a, b) Selective nephroangiography 7 day (ster biopsy). Large triangular parenchymal defect laterally in the intermediate part of kidney probably due to infarction. Arteriovenous fistula with contrast filling faintly discernible in inferior renal ca. (b) Selective nephroangiography 10 day later. The defect persists but is slightly smaller; the fistula has closed.

revealed arteriovenous fistulas immediately after biopsy and MENO & FLANN reported 2 similar cases among their 18 cases subjected to angiography at a corresponding time. Great deviation otherwise occurs in the interval between the biopsy and angiography. A great many cases were examined during the first week after the biopsy but angiography was sometimes not performed for 18 months following the renal puncture.

ERLUND encountered arteriovenous fistulas one week after biopsy in 20 of 41 cases in experimental nephroangiographies following puncture of the kidneys in the rabbit. Repeat angiography two months later disclosed that 14 fistulas had closed, 3 had decreased in size and 3 were unchanged. Neither SWIFT *et coll.* nor MÜLLER *et coll.* in corresponding experiments in dogs were able to demonstrate any arteriovenous fistulas.



FIG. 8 Case 7. Selective nephroangiography 2 day after biopsy. a) Catheter in an artery to the intermediate part of the kidney. Large arteriovenous communication directly into inferior vena cava as early as the arterial phase. b) Oblique. The fistula lies deep in the renal parenchyma.

Such fistulas were detected in 9 of the present 50 nephroangiographies. The angiography was performed 2 to 3 days after biopsy in all but one case, one in which the interval was seven days. The biopsy needle had penetrated 2 to 3 cm within the renal contour in 5 cases; in the remainder of the cases the fistulas formed about 10 mm under the renal contour. The cases also had a triangular ischaemic zone around the site of the fistula. Contrast medium leakage always occurred at the site although the fistulas otherwise varied considerably in both localization and size: they were classifiable as small in 4 cases, medium sized in 3 and large in 2 cases. Four cases presented a mass in the contour around the puncture site, definite overrepresentation compared with the other cases. Haematuria and pain in the side were also appreciably more frequent than in the rest of the material. Hypertension was present in 6 cases. Biopsy disclosed abnormality in 8 of the 9 angiographies.



Fig. 7. Case 6. a) Semi-selective nephroangiography 7 days after biopsy. Large triangular parenchymal defect laterally in the intermediate part of kidney probably due to infarction. Arteriovenous fistula with opacum filling faintly discernible in inferior vena cava. b) Selective nephroangiography 10 days later. The defect persists but is slightly smaller; the fistula has closed.

revealed arteriovenous fistulas immediately after biopsy and MENDO & ILAIN reported 2 similar cases among their 18 cases subjected to angiography at a corresponding time. Great deviation otherwise occurs in the interval between the biopsy and angiography. A great many cases were examined during the first week after the biopsy but angiography was sometimes not performed for 18 months following the renal puncture.

EKELUND encountered arteriovenous fistulas one week after biopsy in 20 of 41 cases in experimental nephroangiographies following puncture of the kidneys in the rabbit. Repeat angiography two months later disclosed that 14 fistulas had closed, 3 had decreased in size and 3 were unchanged. Neither SVENET *et coll.* nor MÜLLER *et coll.* in corresponding experiments in dogs were able to demonstrate any arteriovenous fistulas.

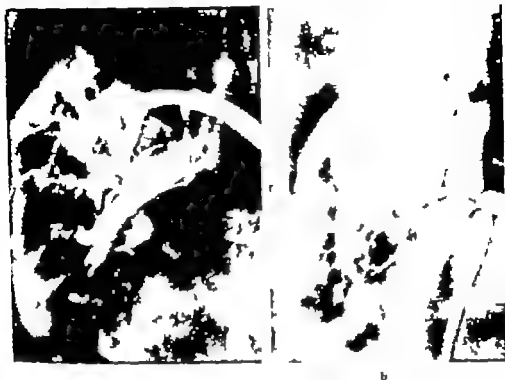


Fig 8 Ca 7 Selective nephroangiography 2 days after biopsy a) Catheter in an artery to the intermediate part of the kidney. Large arteriovenous communication directly into inferior vena cava as early as the arterial phase b) Oblique. The fistula lies deep in the renal parenchyma

Such fistulas were detected in 9 of the present 50 nephroangiographies. The angiography was performed 2 to 3 days after biopsy in all but one case; one in which the interval was seven days. The biopsy needle had penetrated 2 to 3 cm within the renal contour in 5 cases; in the remainder of the cases the fistulas formed about 10 mm under the renal contour. The cases also had a triangular rehaemic zone around the site of the fistula. Contrast medium leakage always occurred at the site although the fistulas otherwise varied considerably in both localization and size: they were classifiable as small in 4 cases, medium sized in 3 and large in 2 cases. Four cases presented a mass in the contour around the puncture site, definite overrepresentation compared with the other cases. Haematuria and pain in the side were also appreciably more frequent than in the rest of the material. Hypertension was present in 6 cases. Biopsy disclosed abnormality in 8 of the 9 angiographies.



Fig. 9 Case 7. Aortic nephroangiography. Flow into the selectin investigation. Triple arteries to both kidneys with fistula right kidney.

Case 5 Woman aged 53 with evidence of tubular necrosis and severe hypertension. Pain referred to the kidney region occurred after the biopsy and selectin nephroangiography three days following it revealed a relatively superficial arteriovenous fistula of medium size with a small ischaemic zone towards the periphery (Fig. 6).

Case 6 Woman aged 19 with evidence of proliferative glomerular nephritis at biopsy followed by abdominal and back pain with macroscopic haematuria. BP 140/100 mm Hg. A perirenal haematoma was considered possible. Selectin nephroangiography was performed seven days after the biopsy. A relatively large wedge-shaped defect of the intermediate part of the kidney from the surface to a depth of 25 mm was associated with a fistula of medium size at the apex of the triangle. A fairly large formation haematoma-like in appearance lay along the lateral contour of the kidney (Fig. 7a). Selectin angiography 10 days later demonstrated a persistent though somewhat decreased defect but no fistula and no haematoma (Fig. 7b).

Case 7 Woman aged 58 with evidence of chronic inflammation of the kidney at histology and considerable hypertension. A sample of urine after biopsy contained numerous erythrocytes. Selectin nephroangiography two days later revealed a central arteriovenous fistula with a free flow into the inferior vena cava (Fig. 8). The kidney had multiple arteries. Complementary aortography disclosed bilateral triple arteries (Fig. 9).

Discussion

Biopsy is usually performed today under the control of TV fluoroscopy. The biopsies in the present investigation were carried out by the previously mentioned method partly because of the radiation hazard. The incidence of clinical complications was not high compared with other materials and this system seems in practice to be suitable.

Extravasation of contrast medium in nephroangiography is probably to be expected after all biopsies when such a well vascularized organ as the kidney is perforated by a large cannula. The frequency of extravasation of medium was even high in LUNDSTROM's large material when the puncture was followed immediately by nephroangiography. An interval of just 2 to 3 days appears to change the situation. LUNDSTROM had a 73 per cent frequency of partly extra-renal extravasation while only 24 per cent occurred in the present material all being intrarenal. Large perirenal leakage of contrast medium was observed by LUNDSTROM particularly in connection with arteriovenous fistulas. The present cases with fistulas had no such leakage, but a soft tissue mass in association with the kidney contour was demonstrated in 4 of the 9 cases. Only 3 haematomas in all were present in the rest of the cases.

Clinical signs were insignificant or absent in all but one of the cases with bleeding. This agrees with the observations made by ZACHORNAK *et coll* as well as LUNDSTROM and contradicts the assertion of KARA *et coll* (1958) that even a small haematoma will cause great discomfort. Peripheral cortical ischaemic defects immediately after needle biopsy are nephroangiographic changes that probably only LUNDSTROM has previously reported. Such changes in a few cases that were controlled later either persisted unaltered or disappeared. The changes had however increased somewhat in one of 2 of the present cases that were re-examined a few days after the first angiography whereas they were slightly less in the other case. The cortical defect resembled infarction. Descriptions in the literature of renal infarcts caused by biopsy and revealed at post mortem examinations are infrequent. On the other hand small scars on the surface of the kidney after puncture have sometimes been observed. The present investigation probably also fails to provide a definite answer to the question as to the exact cause of the cortical defects.

Reason on the whole appears to exist to count on fairly large individual variations in the sequelae to biopsy as indicated by the completely negative angiographic findings sometimes recorded. Most authors describe such cases in their series. It is worth noting that even ZACHORNAK *et coll* were unable to detect the puncture site in 5 out of 29 cases when they freed the kidney by operation at 2 to 4 days after the biopsy.

Arteriovenous fistulas occurred in 18 per cent of the present material. BENNETT & WIENER reported them in 17 per cent of their cases. EARLUM & LINDHOLM in 14 per cent and LUNDSTROM in 11 per cent of cases. The last mentioned stated that fistulas may appear and grow in size soon after biopsy and thus escape detection at the subsequent angiography. This is possibly why the incidence was higher in the present series than reported by LUNDSTROM. Fistulas have however a marked tendency to close in the longer term as illustrated by

the present and many other published cases. As regards the formation of arteriovenous fistulas, it is worth remembering the observation made in animal experiments that needle biopsy causes fistulas in the kidney of the rabbit fairly readily but never in the canine kidney (EKLUND, MÜLLER *et coll.* SWEET *et coll.*).

A significant correlation has been established between the origin of an arteriovenous fistula and the puncture site. All of the illustrations given by BENNETT & WIENER had a puncture track that was deep and central. The puncture had been performed with the patient sitting which can hardly be the most practical position for biopsy. Central punctures occurred as well in most of the fistulas reported by EKLUND & LINDHOLM and LUNDSTROM. Four of 9 punctures in the present material were superficial and only 10 mm from the surface of the kidney. The greater tendency for fistulas to form after central puncture is a natural consequence of the greater likelihood that the point of the needle may damage large vessels.

An increased tendency to fistula formation has also been considered to be associated with hypertension and more serious kidney diseases. All the patients with fistula in the series of BENNETT & WIENER as well as most of those of LUNDSTROM and the present cases had hypertension. LUNDSTROM had moreover to admit that serious angiography changes were significantly more common in the hypertoma group of his series than in the non hypertoma group. No increased tendency towards complications, and especially arteriovenous fistulas in connection with renal disease occurred in the present material. All the cases without biopsy changes disclosed by angiography had mostly glomerular nephritis of different types. The histology was sometimes normal with angiographic changes thus occurred even in a patient with an arteriovenous fistula.

A central puncture site and hypertension appear to be the main causes of the most serious complications, i.e. arteriovenous fistulas and haematomas. The frequency of sequelae represents in general a considerable range of fluctuation from author to author but seems to have a common denominator. A small material of a relatively inexperienced worker appears usually to have a distinctly higher frequency of complications than a large series from the larger urology centres.

SUMMARY

A material of 50 renal biopsies in 48 patients was controlled by nephroangiography for up to 1 week. No changes were observed in 33 examinations while an intrarenal leakage of contrast medium was revealed 10 times and peripheral ischaemic defects were evident on 12 occasions. Further complications are also reported. An increased tendency towards sequelae appeared to be associated with hypertension and central puncture of the kidney.

ZUSAMMENFASSUNG

Ein Material von 50 Nierenbiopsien bei 48 Patienten wurde durch Nephroangiographie bis zu einer Woche nach der Biopsie kontrolliert. Bei 19 Untersuchungen wurden keine Veränderungen beobachtet, während eine intrarenale Leckage des Kontrastmittels 10 mal und periphere mechanische Defekte in 12 Fällen festzustellen waren. Über weitere Komplikationen wird ebenfalls berichtet. Eine steigende Tendenz zur Folgerscheinung scheint mit Hypertonie und einer zentralen Punktion der Niere verbunden zu sein.

RÉSUMÉ

Une série de 50 biopsies rénales chez 48 malades a été contrôlée par angiographie rénale dans la semaine suivant la biopsie. On n'a pas constaté de modification dans 19 examens, une fuite intrarénale du moyen de contraste a été mise en évidence 10 fois et des lésions chimiques périphériques ont été mises en évidence dans 12 cas. Les auteurs ont aussi constaté d'autres complications, la fréquence desquelles paraît augmentée dans les cas d'hypertension et dans les cas de ponction centrale du rein.

REFERENCES

- BROUET A. R. and WIENER S. N.: Intrarenal arteriovenous fistula and aneurysm. *Amer. J. Roentgenol.* 93 (1965) 372.
- BROUET E. and KOWLER R.: Renal arteriovenous fistula. *Acta radiol.* 57 (1962) 433.
- DRACHMANN G.: Morphologische Folgen der Nierenpunktion. *Experimentelle und klinisch-pathologische Befunde*. Springer Verlag Berlin 1969.
- EKLUND L.: Arteriovenous fistulae secondary to renal biopsy. An experimental study in the rabbit. *Acta radiol. Diagnoses* 10 (1970) 218.
- Spontaneous closure of arteriovenous fistula following percutaneous renal biopsy. *Acta radiol. Diagnoses* 11 (1971) 289.
- and LINDHOLM T.: Arteriovenous fistulae following percutaneous renal biopsy. *Acta radiol. Diagnoses* 11 (1971) 38.
- ELION M., MINO G. H. and DE PAREDES R. G.: Correlation of intrarenous urography and renal angiography in kidney injury. *Radiology* 86 (1966) 996.
- FERNSTROM I. and LINDSLOM K.: Selective renal biopsy using roentgen television control. *J. Urol.* 88 (1967) 709.
- HALLERIN M.: Spontaneous closure of traumatic renal arteriovenous fistulas. *Amer. J. Roentgenol.* 107 (1969) 730.
- IVERSEN P. and BAUM C.: Aspiration biopsy of the kidney. *Amer. J. Med.* 11 (1951) 314.
- KARK R. M., MCDONNELL C., POLLAK V. E., PIRANI C. and KIEFER J. H.: An analysis of five hundred percutaneous renal biopsies. *Arch. intern. Med.* 101 (1958) 459.
- LUNDSTROM B.: Angiographic abnormalities following percutaneous needle biopsy of the kidney. *Acta radiol.* (1972) Suppl. No. 31.
- MINO C. H. and ELION M.: Intrarenal angiographic manifestation of iatrogenic renal injury due to percutaneous needle biopsy. *Radiology* 100 (1971) 335.

- MÜLLER J. H. A., ERDMANN T., MAY G., NEUPERT F. und TRIEU N. B.: Angiographischer Nachweis frischer Funktionsfolgen an der Hundenniere. Eine tierexperimentelle Studie zur Nierenbiopsie mit der Menghini-Kanüle. *Z. Urol. Nephrol.* 62 (1969) 73.
- OLSON O. and LÄNDERQVIST A.: Angiography in renal trauma. *Acta radiol. Diagnosis* 1 (1963) 1.
- SWEET E. I., DAVIDSON A. J. and HAYLETT J. I.: Complications of needle biopsy of the kidney in the dog. *Radiology* 92 (1969) 849.
- ZACHORNAY M., KRECH E. und JUSTUS J.: Operativ kontrollierte Lokalbefunde nach perkutaner Nierenbiopsie mit dem Menghini-Instrumentarium bei urologischen Patienten. *Z. ges. inn. Med.* 23 (1968) 97.

RENAL BLOOD FLOW DETERMINED BY ANGIOGRAPHY

G LINGGARDH and B LUNDSTRÖM

In addition to providing morphologic data, nephroangiography can also give some idea of the renal circulation. Thus various morphologic criteria such as the calibre of the renal artery and renal size have previously been proposed (LUDIN *et coll* 1967) as parameters for the estimation of the renal plasma flow. Although the calibre of the renal artery is frequently reduced in chronic, atrophic renal disorders the conditions may vary in acute states. It is a wellknown fact that the cortical circulation is often greatly reduced in acute renal failure despite the fact that the size of the kidney is unaltered or at times increased (HOLLENBERG *et coll* 1971). Consequently, estimations of the renal blood flow based on such morphologic criteria as renal artery calibre or renal size are unreliable. On the other hand a detailed analysis of the passage of contrast medium through the kidney might provide more certain information. In the present report the data obtained from nephroangiography is compared with the renal blood flow as determined by the dye dilution method.

Material Thirty selective nephroangiographies were assessed. The material includes kidneys with normal parenchyma as well as kidneys with various parenchymatous disorders. The clinical diagnoses were based on appraisals made upon completion of hospital investigations generally including renal biopsy. In total

Submitted for publication 4 March 1974

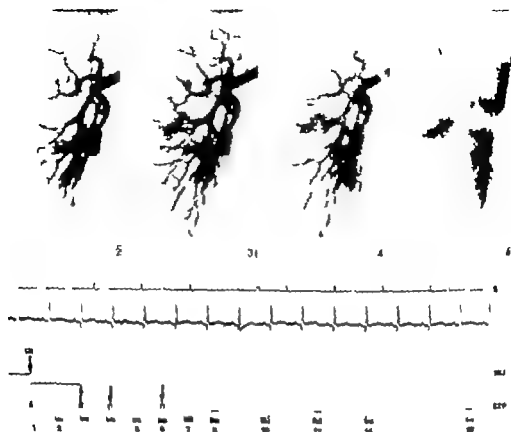


FIG. 1. Normal selective nephroangiography with recording of time (in seconds), ECG, injection time and exposure rate. The distance between A and B represents the injection time. C the exposure of film 4 in the series, the last film with contrast medium remaining in the arteries. Time from the start of the injection to film 5 is the arterial wash out time (21 s). D represents the exposure of film 11, the first film with contrast medium in the renal vein. The distance between A and D represents the venous appearance time of contrast medium (6 s). RBF 560 ml/min by the dye dilution method.

cases angiography was performed on normal kidneys in which the renal circulation had previously been reduced by injecting 10 microgram of adrenalin into the aorta.

Methods. Determinations of the renal blood flow (RBF) and venous appearance time of dye in connection with selective nephroangiography were carried out as described previously (LINGGARDH *et al.* 1969; LINGGARDH 1971; LINGGARDH & LUNDSTROM 1972). In the nephroangiography 10 ml of contrast medium (Urografin 60 c) were injected by a pressure injector using a pressure of

ARTERIAL
WASH-OUT
TIME

Fig. 2 Relationship between arterial wash-out time (in seconds) measured in the aid of recorded injection and exposure data and angiographic films and RBF determined by the dye dilution method. Each kidney represented by \square .

35 kg/cm. The resultant injection time was 10 to 11 s. The rate of exposure was two films per second during the first four seconds, followed by one film per second during another three seconds and a final film after an additional two seconds. ECG, injection and exposure data (Fig. 1) were recorded on a polygraph. The same film changer and pressure injector was used in all cases. The rate of passage of the contrast medium through the kidney was assessed both by observing when the medium had completely disappeared from the intrarenal arteries and by noting the earliest time at which it could be observed in the renal vein. These times were determined with the aid of the recorded injection and exposure data. In the following account the time required for the medium to disappear from the intrarenal arteries will be referred to as the arterial wash-out time as suggested by ABRAMS (1972). The time from the beginning of the injection to the first film in which the medium begins to appear in the renal vein is called the venous appearance time of contrast medium. Other designations for this such as circulation time and transit time are also used in the angiographic literature.

In two cases the renal blood flow was measured after the injection of adrenalin and repeat angiography was done after further injection of adrenalin. In connection with these examinations a separate arterial catheter had been introduced into the aorta. The tip of this catheter was positioned about 8 cm above the origin of the renal artery. After the catheter had been filled with the adrenalin solution and a short time had been allowed to pass in order to eliminate the possible effect of superfluous solution, 10 microgram of adrenalin were injected through the catheter. Dye dilution measurements were performed 5 min after the injection of adrenalin. After it had been ascertained with the aid of new curves that the effect of adrenalin had passed over, nephroangiography was performed 10 to 15 min later, this time also beginning 5 seconds after the injection of another dose of adrenalin.

Tabl

Material

Renal blood flow (ml/min)	N. of examinations	Diagnoses	
> 450	14	Normal	14
450-350	8	Normal	9
		Exudative nephritis	6
350-250	5	Glomerulonephritis	2
		Pyelonephritis	1
< 250		Glomerulonephritis	
		Nephrosclerosis	1
		Normal after injection of adrenalin	2

Results

The renal blood flow determinations by the dye dilution method revealed that the flow ranged from normal to greatly reduced values in the different examinations. These 30 examinations were divided into four groups according to the RBF values found (Table). On checking the exposure recordings the rate of exposure was found to be somewhat slower than the preset rate. Thus, the computed arterial wash out time was corrected to 2.1 s, 2.6 s, 3.2 s etc. (instead of preset 2.0 s, 2.5 s, 3.0 s etc.). The relationship between the renal blood flow measured by the dye dilution method and the arterial wash out time appears in Fig. 2. In the group with the RBF exceeding 450 ml/min the arteries were devoid of contrast medium after 2.1 seconds in 8 cases. In these examinations film 4 was the last film in which the medium was still present in the arteries and film 5 was the first in which they were devoid of contrast medium (Fig. 1). With renal blood flows of this magnitude the time was 2.6 s in 5 additional cases and 3.2 s in one case.

In the group with an RBF of 350 to 450 ml/min the arterial wash out time was 3.2 s or more in 5 out of 8 examinations. When the RBF was less than 350 ml/min the corresponding time was, as a rule, 3.7 s or more (Fig. 3). In the two cases in which adrenalin was injected the RBF decreased to less than 250 ml/min. One of these examinations is demonstrated in Fig. 4. The angiographic findings in these cases with the adrenalin effect deviated only little from those of the other kidneys in this group (2 cases of glomerulonephritis and 1 case of nephrosclerosis). Thus, in all the examinations the intrarenal arteries decreased in calibre fairly suddenly subcortically, so that no filling of cortical arteries could be observed. In the two adrenalin cases the arterial wash-out time was 5.3 s.

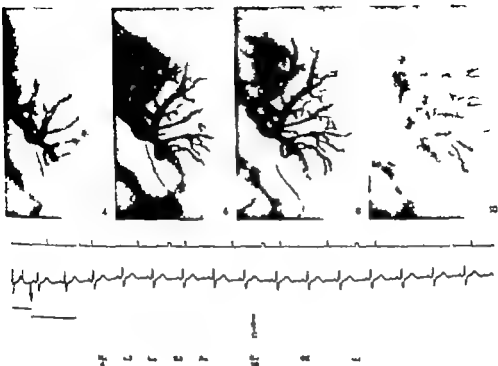


Fig 3 Films 4 6 8 and 10 from angiographic film sequence in case of glomerulonephritis. Arterial ash out time 5.3 RBF 210 ml/min

In 10 examinations with an RBF of more than 450 ml/min initial contrast filling of the renal vein could be linked with a specific film in the angiographic film sequence. In these cases the venous appearance time of contrast medium averaged 3.6 s (2.6 to 4.9 s). The appearance time in dye dilution determinations in corresponding cases averaged 2.9 s (1.8 to 3.9 s). In cases with severely reduced renal blood flow there was usually only a slow increase of contrast medium in the renal vein and the first film with medium in the vein could not be determined with certainty. An exact computation of the appearance time of contrast medium was thus rendered impossible.

DISCUSSION

Under normal conditions the flow of blood to the renal cortex makes up 80 to 90 per cent of the total renal blood flow (THORNBURN et coll 1963 TRUNIGER et coll 1966 and others). If cases of severe stenosis of the renal artery are excluded with normal blood pressure and blood viscosity the renal blood flow is

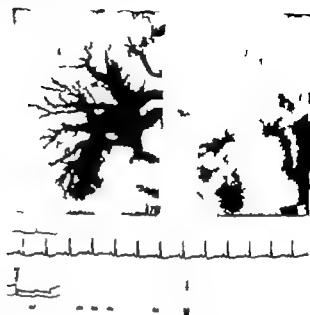


Fig. 4. Films 7 and 12 after intra-arterial injection of adrenalin. Arterial wash out time 3.5 RBF: 180 ml/min.

mainly dependent on the peripheral resistance of the renal vascular bed. In recent years reduced blood flow through the cortical tissue has been demonstrated by means of examinations with xenon as well as other methods in various acute renal disorders such as tubular nephritis, acute rejection of renal transplants and reactions to nephrotoxins (REITEK *et coll* 1967, HOLLENBERG *et coll* 1968). A form of active selective vasoconstriction in the cortex has been postulated in such cases (DANIEL *et coll* 1952, HOLLENBERG *et coll* 1971). In spite of reduced renal blood flow the kidney may sometimes be enlarged in these cases owing to parenchymal oedema. In epidemic nephritis (nephropathia epidemica of Scandinavia) the blood flow to the kidney is of normal magnitude or slightly reduced despite the fact that the renal artery is dilated and the size of the kidney is frequently increased as the result of interstitial oedema (LINGGARDH *et coll* in press). The angiographically measured size of the kidney and width of the renal artery therefore seem to be inadequate parameters for assessing the renal blood flow. A recently suggested method for computing the RBF from the volume of the cortical tissue (GOTHILIN *et coll* 1973) is equally unsatisfactory.

As has been shown by among others ABRAMS *et coll* (1962) and EPSTEIN *et coll* (1968) peripheral renal vasoconstriction can be induced by injection of adrenalin. When angiography is performed under these circumstances reduced filling of the peripheral cortical vessels occurs. ABRAMS (1972) also points out the possibility of relating the renal blood flow to the contrast filling of such intrarenal

peripheral vessels as the arcuate and interlobular arteries. Although reduced filling of the cortical renal vessels often exists in renal disorders with diminished renal blood flow, an acute inflammatory renal disorder such as epidemic nephritis can in direct contradiction to the rule lead to increased filling of the interlobular vessels (LINDGARDH *et coll.* in press).

As has been demonstrated by BOLIN (1966) the renal blood flow, as well as renal function, can be evaluated by means of densitometric measurements made directly from angiographic films. In principle, however, differences exist between renal blood flow examinations and those performed in other vascular regions such as the brain. BOLIN points out that in addition to varying with the renal function, the uptake of contrast medium in the kidney also depends on the injected amount of medium and the rate of injection used. It is also possible that the circulation time may be shortened in cases with impaired renal function if too large an amount of medium is used in relation to the renal blood flow. Because of methodologic difficulties and uncertainty concerning the accuracy of the technique, it has not come into more widespread clinical use.

As has been demonstrated previously (LINDGARDH & LUNDSTROM 1972) in dye dilution measurements the appearance time for dye in the renal vein varies in different renal diseases. Thus, as a rule, conditions with low blood flow, such as chronic pyelonephritis, nephrosclerosis and glomerulonephritis, generally displayed prolonged appearance times. Consequently, it would seem to be possible that determinations of the appearance time of contrast medium in the renal vein could be used to estimate the renal blood flow in angiography. If no renal disease was present, it was found that on an average the contrast medium began to appear 3.6 s after contrast injection. The corresponding time after dye injection was 2.9 s. In cases with impaired renal blood flow, only a slow increase of contrast medium in the renal vein was noted. In such cases the first film with medium in the renal vein could not be determined with certainty. Even if the amount of injected medium was increased, demonstration of the renal vein was insufficient when the renal blood flow was severely reduced. Consequently, estimations of the RBF based on assessment of the venous appearance time of contrast medium produce unreliable results in cases of renal disease with impaired blood flow.

Unlike the venous appearance time of contrast medium, the arterial wash-out time can be determined in renal disease with impaired renal blood flow. In cases with normal renal blood flow, the arterial wash-out time ranged between 2.1 and 3.2 s, which agrees well with the normal limits (1.5 to 3 s) found by ARBMAN (1972). With the exception of one case the arterial wash-out time was prolonged when the RBF was less than 50 ml/min. The error in determinations of the arterial wash-out time with this technique and rate of exposure used here is less than 0.5 s during the most important part of the examination.

Thus, in a simple manner the arterial wash out time seems to give a fairly good idea of the renal blood flow. Since nowadays injection and exposure data are generally recorded in most departments where nephroangiography is performed the angiographic examination can readily be adapted also to provide information on the renal blood flow. The rate of injection should be rapid enough to yield high contrast concentration in the intrarenal arteries. If the injection is started at the same time as the first film is exposed as is the custom and the rate of exposure during the following seconds is two films per second it seems that the following rule of thumb could be established. If the fourth film is the last one with contrast medium in the arteries, the renal blood flow is in all probability normal (arterial wash out time < 2.1 s) and, as a rule, the sixth film represents a moderately reduced blood flow while the persistence of contrast medium in the arteries up to and including the tenth film indicates a severely reduced blood flow (< 250 ml/min).

Even though the method proposed here for assessing the renal blood flow on the basis of the arterial wash out time only yields approximate values it should be suitable for use in the clinic. Compared with the methods in which the RBF is calculated from the measured size of the kidney or the computed volume of the cortical tissue it has the advantage of being able to register such changes in the blood flow as are caused by altered peripheral resistance without a demonstrable change in the size of the kidney.

Acknowledgement

This investigation was supported by grants from the Swedish Cancer Research Foundation. Proj. N. 12 B73 09%.

SUMMARY

The renal blood flow was determined by the dye-dilution method concurrently with selective nephroangiography in 30 examinations. Different angiographic parameters for assessment of the renal blood flow are discussed. The time elapsing from the start of contrast injection until the intrarenal arteries become devoid of contrast medium (the arterial wash out time) corresponded fairly well with the magnitude of the blood flow in the kidney. Among other things estimates of the renal blood flow based on the arterial wash-out time take account of the circulatory conditions in the renal cortex and should therefore be clinically useful.

ZUSAMMENFASSUNG

Der renale Blutstrom wurde gleichzeitig mit der Farbstoff-Verdünnungsmethode und der selektiven Nierenangiographie in 30 Fällen untersucht. Verschiedene angiographische Parameter für die Bestimmung des renalen Blutstroms werden diskutiert. Der Zeitverlauf von

Begun der Kontrastinjektion bis zum Zeitpunkt zu dem die intrarenalen Arterien frei von Kontrastmedium wurden (die arterielle Wash-out Zeit) entsprach ziemlich gut der Grösse der Durchblutung der Nieren. Unter anderem berücksichtigen Bestimmungen der Nieren durchblutung die auf der arteriellen Wash-out Zeit beruhen die zirkulatorischen Bedingungen der Nieren und sollten deshalb von klinischem Wert sein.

RÉSUMÉ

Le débit sanguin renal a été déterminé par la méthode de dilution de colorants en même temps que par la néphro-angiographie sélective au cours de 30 examens. Les différents paramètres angiographiques pour évaluer le débit sanguin renal. Le temps qui s'écoule entre l'injection de contraste jusqu'à ce que les artères intrarénales soient dépourvues de moyen de contraste (le temps de la zone artérielle) correspond assez bien à l'importance du débit renal déterminé. Entre autres choses les estimations du débit sanguin renal basées sur le temps de lavage artériel tiennent compte des conditions circulatoires dans le cortex renal et devraient donc avoir un intérêt clinique.

REFERENCES

- ABRAMS H L. Quantitation der renalen radiologischen studies. An overview. *Invest Radiol* 7 (1972) 240.
- BOGNER E and BOWENFORD H E. Effect of epinephrine on the renal circulation. *Angiographic observation*. *Radiology* 79 (1967) 911.
- BOLIN H. Contrast medium in kidney during an angiography. *Acta radiol* (1966) Suppl. N 237.
- DARRELL P M, PEARBODY C N and PRIGGARD M M L. Cortical ischaemia of the kidney with maintained blood flow through the medulla. *Quart J exp Physiol* 37 (1952) 11.
- EPSTEIN M, HOLLINGERER N H, BASCH R I and MERRILL J P. The effect of epinephrine on the intrarenal blood flow distribution in man. *Clin Res Proc* 16 (1968) 59.
- GOTTLIEB J, HECHTSON V and OLIV T. Relations between blood flow, arterial cross sectional area and total and cortical volumes of the kidney. *Acta radiol Diagnost* 14 (1973) 106.
- HOLLINGERER N H, EPSTEIN M, ROSEN S M, BASCH R I, OLIV D E and MERRILL J P. Acute oliguric renal failure in man: evidence for preferential renal cortical ischaemia. *Medicine* 47 (1968) 455.
- BASCH R I and MERRILL J P. No man's land of the renal vasculature: an arteriographic and hemodynamic assessment of the interlobar and arcuate arteries in essential and accelerated hypertension. *Am J Med* 47 (1969) 845.
- ADAMS D F, MERRILL J P and ABRAMS H L. Renal angiography in oliguria. *J Angiography*. Edited by H L Abrams, L L Brown and Co. New York (1971) p. 88.
- LEWANDER G. Studies on separate renal blood flow and function using a dye-dilution technique and radiochemicals. *Scand J Clin Nephrol* (1971) Suppl. No. 8.
- and LEWANDER G. Renal blood flow in man studied with dye-dilution method. *Scand J Urol Nephrol* 6 (1972) 54.
- and NYSTRÖM K. Renal blood flow in acute epidemic nephritis. *Scand J Urol Nephrol*. In press.
- MURTA T and OLIV T. Renal blood flow in dogs studied by means of dye-dilution technique. *Scand J Urol Nephrol* 3 (1969) 261.

- LUDIN H., FLÄCK M., FÄHR H. and THORLEN H.: Correlation of renal size, renal artery calibre and effective renal plasma flow in man. *Acta radiol. Diagnosis* 6 (1967) 296.
- REITER A. B., HOLLENBERG N. K., ROSEN S. M., MERRILL J. P. and MURRAY J. F.: Cortical ischemia in renal allograft rejection. *Surg. Gynec. Obstet.* 124 (1967) 980.
- THORSTERN G. D., KOPALD H. H., HARD J. A., HOLLENBERG N. K., O'MOCHS C. C. C. and BARGER A. C.: Intrarenal distribution of nutrient blood flow determined with krypton-81 in the unanesthetized dog. *Circulat. Res.* 13 (1963) 290.
- FRUMKIN E., ROSEN S. M. and OREN D. F.: Renale Hamodynamik und hamorrhagische Hypotension. *Klin. Wochschr.* 44 (1966) 857.

THE ILIAC COMPRESSION SYNDROME

KJELL ÅKE JOHANSSON BENGT GOTHMAN and SAM NORDSTRÖM

The iliac compression syndrome (COCKETT & LEA THOMAS 1963) is a condition of venous congestion in the small pelvis starting at the confluence area and radiating to one of the legs. The symptoms are predominantly left sided but may also occur on the right side. The venous drainage from the legs is obstructed sometimes to such an extent that thrombosis may arise. Depending on the localisation of the obstruction various channels of collateral circulation are established. Detailed investigations concerning these problems have been carried out by LEA THOMAS *et al.* (1963).

The right common iliac artery crosses the left common iliac vein on the anterior aspect of the vein approximately at the level of the promontory. In frequently this intimate relationship of artery and vein may result in venous obstruction. MAY & TURNER (1956) stated that the back and front walls of the vein are brought into contact with one another by means of transmitted arterial pulsations resulting in chronic inflammatory conditions of the vein. Endothelial proliferation causing narrowing of the venous lumen in the confluence area or its tributaries have been recorded at autopsy. Thus in 22 per cent out of 430 autopsies abnormalities of the wall were found in the common iliac vein close to the confluence ranging from slight, valve-like formations

Fig. 1 The distal part of the inferior vena cava and the confluence area seen from behind. Different degrees of occlusion of the venous lumen due to intimal proliferations from small shelflike formations (almost total obliteration of the lumen) (Courtesy M. & THURNER).



growing into the lumen from the medial and lateral sides to almost total occlusion of the venous lumen (MAY & THURNER, Fig. 1). Histologically these changes were consistent with those appearing in chronic unspecific inflammation and in no case could they have been mistaken for a recanalized thrombus.

The symptoms and signs are uncharacteristic in many cases consisting only of a slight to moderate swelling of the leg. Varicose veins of the leg may occur but are not obligatory. Most cases are women, usually young or in early middle life.

This condition has previously been investigated by COCKRFT & LEA THOMAS who performed peritrochanteric phlebography, and by LEA THOMAS et coll (1968) who did separate phlebo- and aortographies under exactly comparable conditions. By means of a modified subtraction procedure the mutual relationships between vein and artery were well illustrated.

Material and Methods. During the years 1968 to 1971 this condition was encountered in seven patients, all women. In the beginning the mode of examination was not uniform but has become so gradually, and at present consists of the following procedures presented in the order in which they are performed.

A Pelvic phlebography in supine position. Puncture of both femoral veins, insertion of teflon catheters connected by a $\frac{1}{2}$ tube and injection of 50 ml I opaque Cerebral within 17 s. If obstruction to the inflow into the inferior vena cava is demonstrated resulting in filling of the left ascending lumbar vein or collateral circulation from the left to the right side via the presacral and parametral plexus or the pubic vein, the examination is supplemented with a pressure recording.

B Recording of the intravenous pressure. is performed in supine position by means of the two injection catheters, which are placed in the inferior vena cava. They are then moved peripherally to each common iliac vein during continuous recording of pressure.



Fig. 2. a) Pelvic phlebography. Compression on left side just peripheral to the confluence. Wide left iliofemoral vein filled. Collateral circulation from left to right in the perineal plexus. b) Simultaneous pelvic phlebography and aortography. An overriding left common iliac artery is the cause of the venous compression.

C Pelvic phlebography in prone position (see further under A).

D Recording of the intravenous pressure in prone position (see further under B).

E Simultaneous pelvic phlebography and aortography. One femoral artery is punctured and a third catheter is inserted with its tip in the middle part of the abdominal aorta. Simultaneous injection by means of two pressure syringes.

Case reports

CASE 1. A woman aged 29 had intermittent claudication of the legs for 5 months and when admitted to hospital had had swelling of the legs for 2 days. Angiography revealed thrombosis at the confluence. Simultaneous phlebography and aortography indicated considerable thrombosis developed at the confluence. An iliac thrombectomy was performed as an operation. Local resection of the vein and ligation of the artery was carried out and a dacron graft was inserted. The graft was more than 50 per cent of the lumen of the vein and was encountered. A percutaneous catheter was inserted in the vein and dacron graft. The right iliac artery and the right iliac vein were ligated without discomfort.



Fig 3 Case 3 a Pelvic phlebogram early phase Left common iliac vein considerably wider than the right Collateral circulation from left to right in the presacral plexus Left lumbar ascending vein filled b) Late phase Obstruction to inflow for left common iliac vein c) Simultaneous phlebo- and aortography The compression at the confluence area is caused by right common iliac artery

Case 2 A woman aged 40 had had intermittent swelling of the left leg for several years and mild varicose veins Simultaneous phlebo- and aortography indicated compression of the left iliac vein Increased venous pressure on the left side The findings were confirmed at operation Adhesions between the vein and artery were loosened and the patient condition improved (Fig 2)

Case 3 A woman aged 49 had had swelling of the left leg for 2-3 years Angiography revealed arterial compression of the left common iliac artery and reduced inflow into the vein as well A collateral circulation from left to right was also present At operation severe stenosis of the left common iliac artery was found The obstruction to the venous flow was caused by the left internal iliac artery (LILLY THOMAS et coll 1968) The left internal iliac artery was divided and the adhesions loosened and the condition improved

Case 4 A woman aged 43 had suffered from swelling of the left leg for 4 years Simultaneous phlebo- and aortography revealed obstruction of inflow into the vena cava on the left side and a collateral circulation from left to right Venous compression with thickening of the venous wall was seen at operation After loosening of adhesions between the vein and the artery the condition improved

Case 5 A woman aged 18 had had moderate swelling of the left leg for 2 years Obstructed inflow and a collateral circulation from left to right were established by angiography At operation a fibrous band was found where the vein and artery crossed



b

Fig. 4 Same case as in fig. 3. Operative findings. a) The left common iliac vein is congested and cyanotic, overriding of right common iliac artery evident. b) After ligation of abdominal aorta and ligation of rudimentary caudal artery the left common iliac vein is of ordinary size and appearance.

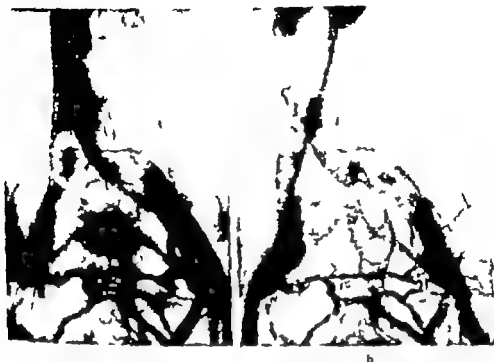


Fig 3 (a, b) Phlebography. Collateral circulation from left to right and venous compression at the confluence area. Widening of the left common iliac vein. Left lumbar ascending vein filled. b) Simultaneous phlebo- and aortography. The impression of the left common iliac vein caused by the tortuous left common iliac artery.

each other. A rudimentary caudal artery, binding the aorta bifurcation dorsally, was divided. A pressure gradient of 8 cm H₂O over the confluence area, as recorded. Adhesions were loosened and the pressure fell to normal after the operation. The patient was completely restored (Figs 3, 4).

Case 6 A woman aged 19 had had swelling of the left leg for more than 2 years. She had been taking oral contraceptives for 6 months before the investigation. Angiography revealed venous compression with a collateral circulation from left to right. Pressure gradient left common iliac vein to crura cava 7 cm H₂O both in supine and prone positions. Preoperatively catheterization with a Fogarty catheter performed. It was filled with 0.5 ml contrast medium resulting in an outer diameter of the balloon of 9 mm. This just enabled the catheter to pass the constricted part of the vein. Both proximal and distally to this narrowed section the balloon could be moved freely. It was filled with contrast medium corresponding to an inner diameter of 13 mm. The patient has not yet undergone operation.

Case 7 A woman aged 42 with a history of swelling of both legs predominantly the left leg for 5 to 6 years. Angiography established venous compression with collateral circulation from left to right. Simultaneous phlebo- and aortography. Venous compression

bilaterally of haemodynamic significance of the left side. Gradient 5 cm H₂O. At operation congested pelvic veins were encountered especially posteriorly. The adhesions were loosened and following the operation the venous congestion diminished noticeably (Fig. 5).

Discussion

Reports based on large surgical and roentgenologic materials of iliofemoral thrombosis indicate that this condition is more common on the left than on the right side occurring approximately in the ratio of 4:1 to 5:1 and that venous congestion is eight times more common on the left than on the right side (BALES & DE WESSE 1966). Since the artery constricts or compresses the iliac vein predominantly on the left side it seems reasonable to suggest that such a mechanism might contribute to congestion of the femoral vein and thrombus formation.

Oral contraceptives may play a role because such medication may cause intrinsic lesions of the veins in the form of endothelial proliferation and intimal thickening (IRBY *et al.* 1970) and increase the propensity of blood for thrombus formation (ASA UPHARA 1966, VESSEY & DOLL 1968). These mechanisms might account for iliofemoral thrombosis having developed shortly after administration of oral contraceptives as demonstrated in one of our patients.

In view of the fact that seven cases have been observed during a three year period at one and the same hospital and observations in the literature concerning this condition are rather few it is surmised that the condition is more common than was formerly believed. It is evident that a correct diagnosis is important since the disorder can be successfully treated. When no abnormalities are encountered at peripheral phlebography performed for possible venous congestion or deep thrombosis supplementary examinations of the pelvic veins, including the confluence and the arteries around the promontory should be carried out. These angiographic examinations should also be supplemented with pressure recordings in the inferior vena cava as well as in the iliac veins in order to obtain a better understanding of the functional significance of the anatomic abnormality demonstrated angiographically.

SUMMARY

The iliac compression syndrome is a condition of chronic congestion in the small pelvis due to sternal compression of the veins. Seven patients with this condition and demonstrating many clinical and roentgenologic features in common are presented. The etiology, indications and technique of examination are discussed as well as the role of oral contraceptives as thrombogenic factor.

ZUSAMMENFASSUNG

Das von Darmbein gebogene Kompressions-Syndrom beruht auf einer erworbenen Stauung im kleinen Becken infolge einer arteriellen Kompression der Venen. Sieben Patienten mit einer deutlichen Veränderung, die im allgemeinen viele derartige klinische und röntgenologische Gesichtszüge zeigen, werden vorgestellt. Die Ätiologie, die Indikationen und die Technik der Untersuchung sowie die Rolle der oralen empfängnisverhütenden Mittel als Thrombose hervorrufender Faktor werden diskutiert.

RÉSUMÉ

Le syndrome de compression iliaque est un état de congestion veineuse dans le petit bassin dû à la compression des veines par les artères. Les auteurs présentent sept malades atteints de cette affection qui ont en commun d'importants caractères cliniques et radiologiques. Les auteurs examinent l'étiologie, les indications et la technique d'examen ainsi que le rôle des contraceptifs oraux comme facteur thrombotique.

REFERENCES

- Mc LEAN E. Thromboembolism and oral contraceptives: post or propter? *A. la med* 179 (1966) 463.
- BULL C. and DEWINTER J. Iliac vein stenosis. *Vascular diseases* 3 (1966) 373.
- COCKETT F. B. and LEE THOMAS M. The iliac compression syndrome. *Brit J Surg* 52 (1965) 816.
- JOY A. S., MANN W. C. and TAYLOR H. B. Vascular lesions in women taking oral contraceptives. *Arch. Path.* 89 (1970) 1.
- LEE THOMAS M., FLETCHER E. W. L., COCKETT F. B. and NORTON D. Collaterals in external and common iliac vein obstruction. *Clin. Radiol.* 18 (1967) 403.
- ASHLEY W. R. and FLETCHER E. W. L. Arterial impressions in pelvic phlebography. *Clin. Radiol.* 19 (1968) 404.
- MER R. und THURMER J. Ein Gefäßportus in der Vena iliac communis sinistra als Ursache der überwiegend hämorrhagischen Beckenvenen thrombosen. *Z. Arztl. Fortb.* 40 (1966) 917.
- LESTY M. P. and DOLL R. Investigation of relation between use of oral contraceptives and thromboembolic disease. *Brit Med J* 2 (1968) 199.

SCLEROSING INJECTION OF ESOPHAGEAL VARICES THROUGH TRANSHEPATIC SELECTIVE CATHETERIZATION OF THE GASTRIC CORONARY VEIN

A preliminary report

A LUNDEQUIST and J VANG

The mortality due to bleeding from esophageal varices is high in patients with portal hypertension (HISLOP et coll 1966 ORLOFF 1967) and only 30 to 50 per cent of patients are reported to leave hospital after the first hemorrhage. Emergency operation with a portal systemic shunt in these debilitated patients is likely to give poor results.

Transhepatic portography in cases with portal hypertension has been used in this department to demonstrate the venous anatomy preoperatively (GÖRANSSON et coll 1974). During this procedure the coronary vein was found easily available for selective catheterization. This was the incentive to try injection of a sclerosing agent in this vein for emergency treatment of bleeding esophageal varices.

Method and Material Transhepatic puncture of the portal vein was performed under local anesthesia through the lateral thoracic wall by the usual

Submitted for publication 16 April 1974



Fig 1 Transhepatic portography in woman and 2) 10th liver cutbosa. Retrograde flow through coronary vein to esophageal aneas through inferior mesenteric vein and paraumbilical vein.



Fig 2 Selective catheterization of coronary vein with injection of contrast medium gives better demonstration of the aneas.



Fig 3 Injection of contrast medium into coronary vein after thrombotization. No aneas filled.



Fig 4 Portography. No retrograde filling of the coronary vein now obliterated by thrombus. Contrast medium in the thrombus (→) after the previous injection.

technique for transhepatic cholangiography. After the needle had been pulled out a guide wire was inserted into the main stem of the portal vein. The catheter was then placed with the tip in the medial portion of the splenic vein. With the catheter in this position 40 ml of Isopaque Coronar was injected. Exposures were made one per second for 8 s and one every other second for 16 s. This allowed the vascular anatomy and flow directions to be demonstrated.

When retrograde flow through the coronary vein was observed and the varices in the fornix of the stomach and the lower esophagus had filled a curved guide wire was introduced through the catheter and manipulated into the coronary vein to the branching close to the cardia. A catheter could then easily be placed with the tip at the same site. Contrast medium was again injected to obtain better information about anatomy and flow directions. When the flow was directed to the esophageal varices 30 ml of glucose 50 % was injected manually through the catheter to produce an intimal injury to the vein, after which the catheter was filled with thrombine solution (Topostann, Roche, Switzerland 3000 NIH U in 10 ml saline). A few drops only were then injected into the coronary vein where a thrombus was immediately formed. The result was checked with a hand injection of contrast medium. When the blood flow through the esophageal varices was blocked by the thrombus small fragments of spongostan (Ferosan Denmark) were injected through the catheter into the thrombus in one case. Two patients only have been treated up till now.

Case report

A woman aged 85 was referred to the hospital with severe hematemesis and melena. After insertion of Sengstaken-Blakemore tube and blood transfusions the bleeding stopped. Three years previously liver carcinoma with ascites and esophageal varices had been diagnosed. During these three years the patient had been hospitalized seven times for severe bleeding from her varices but her condition had not allowed operation. On admission her condition was bad and the anesthesiologist advised against operation under general anesthesia.

At transhepatic portography (Fig 1) wide esophageal varices were filled through the coronary vein which was then catheterized (Fig 2) and thrombosed (Fig 3). At subsequent portography (Fig 4) no filling of the coronary vein or esophageal varices was obtained. The patient has had no recurrence of her bleedings and left the hospital after one week. The subsequent observation period has been short, only two weeks.

Discussion

The treatment of esophageal varices by injection of a sclerosing agent is not new and was first described by CRAFOORD & FRENCANER (1939). They made the injection through an esophagoscope. This method has later been used by FEARON & SASS HORTBAK (1959), ORLOFF (1967) and HUNT et coll (1969).

Fibrosis and thickening of the esophageal wall has been produced by intra-mucosal sclerosing injection through an esophagoscope in inoperable patients with bleeding esophageal varices (KAPP & BUZZI 1973)

The injection of hypertonic glucose and thrombine into the coronary vein in the present case was intended to stop the acute hemorrhage. By blocking the esophageal route of portal-systemic communication other possible spontaneous anastomoses as the inferior mesenteric vein-spleno-renal anastomoses and para-umbilical vein anastomoses to subcutaneous veins may increase in size. The need for spleno-renal or porta-caval shunts may then be reduced. As emergency portal-systemic shunts involve a high mortality a non-operative method of treatment should be preferable.

SUMMARY

Bleeding from esophageal varices was treated by selective injection of sclerosing agent in the transhepatically catheterized gastric coronary vein. A preliminary report is given of the technique and results in the first two patients.

ZUSAMMENFASSUNG

Blutungen aus Ösophagusvarizen wurden durch selektive Injektion von Sklerose bewirkenden Mitteln in die transhepatisch katheterisierte Vena coronaria gastrica behandelt. Es wird ein preliminärer Bericht über die Technik und die Ergebnisse bei den ersten beiden Patienten gegeben.

RÉSUMÉ

Une hémorragie de varices œsophagiennes est traitée par injection sélective d'un agent sclérosant dans une veine coronaire stomacale cathétérisée par voie transhépatique. Les auteurs présentent un rapport préliminaire sur leur technique et sur les résultats chez leur deux premiers malades.

REFERENCES

- CARROLD C and FRENCKNER P. New surgical treatment of varicose veins of the esophagus. *Acta oto-laryng.* 27 (1939) 422.
- FRABOT B and SAM-HORTAK A. The management of esophageal varices in children by injection of sclerosing agents. *Ann Otol (St Louis)* 68 (1959) 906.
- GOTTLIEB J, LEVINSKY A and FYLL U. Selective phlebography of the pancreas. *Acta radiol. Diagnosis* 15 (1974) 474.
- HILLO I G, WATERS T E, KELLOCK T D and SWINERTON B. The natural history of haemorrhage from oesophageal varices. *Lancet* i (1966) 945.

- HUNT P. S., JOHNSON G. W. and RODRIGUEZ H. W. The emergency management of bleeding oesophageal varices with sclerosing injections. *Brit J Surg* 56 (1969) 303.
- KAPP F. und BUZZI H. J. Ösophaguswandsklerosierung als Therapie blutender Ösophagusvarizen bei inoperablen Patienten. Vergleichende Resultate bei 14 behandelten und 14 unbehandelten Patienten. *Dtsch med Wochr* 98 (1973) 2463.
- ORLOFF M. J. Emergency portacaval shunt. A comparative study of shunt operation and nonsurgical treatment of bleeding esophageal varices in unselected patients with cirrhosis. *Ann Surg* 166 (1967) 436.

CHRONIC SYMMETRIC OSTEOMYELITIS

Report of a case

A. H. GUSTAVSON and H. F. WILBRAND

Grimov et coll (1972) under the heading Subacute and chronic symmetrical osteomyelitis described symmetrically distributed osteolytic changes in metaphyseal structures of the lower extremities in four children. The age at onset of the main initial symptoms of limping, pain, local tenderness and swelling was 5 to 11 years, there were no general symptoms apart from occasional periods of fever. The time interval between manifestation of the first symptoms and the roentgenologic diagnosis varied between 5 weeks and 2 years. The laboratory findings were unspecific and suggestive of inflammation. The cultures of pretreatment biopsy material were negative in 3 of the patients but plasma cellular osteomyelitis was diagnosed histologically. In the fourth case pneumococci were demonstrated in the biopsy cultures. Healing occurred after long term treatment by scleroses over periods varying from several months to one year.

A further report of a girl with chronic symmetric osteomyelitis of the type described by these authors is now presented.

Case report

A girl aged 7 years, the second of four siblings in a healthy family with no history of joint or skeletal diseases, had developed normally, she sustained slight trauma of the right

Submitted for publication 30 April 1973



Fig. 1. Chronic symmetric osteomyelitis in the femoral and tibial metaphyses (both legs). (a) Right leg. Multiple roundish radiolucent columns and osteolytic foci in the metaphyses adjacent to the epiphyseal growth plates. Periosteal reaction medially. Sclerosis surrounds the osteolytic foci. Cortical defect evident in femoral epiphysis. (b) Left leg. Osteolytic foci in the femoral and tibial metaphyses with some perifocal sclerosis. No periosteal reaction. No clinical signs.

b

knee which during the following three weeks became moderately stiff with some pain but no swelling, no general changes. The symptoms continued on and off for five months until it was drained.

On admission her general condition was good and she was completely free from symptoms. There were no signs of infection and the condition of the joints was normal. The girl was of normal height for her age. Skeletal roentgenograms revealed bilateral osteolytic changes in the distal femoral metaphyses and the proximal tibial metaphyses (Figs 1, 2), in the upper metaphysis of the right humerus (Fig. 3) and bilaterally in the ischiopubic synchondroses (Fig. 4).

Routine blood and urine tests were normal apart from an ESR of 25 to 26 mm. The white cell count was $7100/\text{mm}^3$ with 5100 polymorphs and 2000 mononuclear leucocytes and a differential count of 65 per cent eosinophils. Liver function tests produced normal results. The serum acid and alkaline phosphatases, the serum calcium and phosphorus and the calcium and phosphorus excretions in a 24 hour urine specimen were all normal. The serum electrophoresis, the sheep cell agglutination test, latex test and antinuclear globulin test were all negative. The antistreptolysin titre (AST) was less than 70 units/ml and the antistaphylococcal titre (ASTA) 4.0 units/ml. A diagnosis of osteochondritis juvenilis (Caffey 1967) was made and no treatment was prescribed.

The patient was readmitted three years later. She had had no symptoms since her previous stay in hospital apart from during the last month when she had had aching in the right knee and groin. The ESR had been between 14 and 40 mm during the last stay at home. On admission physical examination revealed nothing abnormal. Roentgenography indicated regression of the osteolytic lesions with increasing sclerosis. Routine analyses of



Fig 2 Osteolytic lesions eroding the cortical and subcortical bone coalescent with a large defect in the popliteal region of the right knee. The osteolytic foci are surrounded by sclerotic bone.



Fig 3 Chronic osteolytic lesions in the upper metaphysis of the right femur. A lesion lies adjacent to the growth plate with several lesions coalescent with a larger defect surrounded by sclerotic bone.

the blood and urine produced normal results. The white cell count was $5,600/\text{mm}^3$ with 57% polymuclear and 1,900 mononuclear leukocytes. ESR 27 mm. AST is 1.6, ALT 6.4 units/ml and ASTA 1.6 units/ml. Blood culture was negative. Serum electrophoresis presented a pattern compatible with a low-grade process. The immunoglobulin response to tuberculin screening of the urine revealed nothing abnormal. Biopsy was not indicated from an orthopaedic point of view.

She was re-examined two years later following bouts of pain immediately above and below the patella of the right knee especially when walking. There had been no swelling or increase in warmth of the knee but on a few occasions she had complained of pain on the outer aspect of the right hip and the right of the lumbar spine and on the anterior aspect of the right tibia. Three months previously she had had such severe pain in the right knee that she had been unable to bear weight on the leg. Joint function was normal here. She was examined apart from slightly red, ced, outward rotation of the right hip due to pain and some atrophy of the quadriceps and tibial muscles of the right leg. Serum electrophoresis presented a pattern compatible with a chronic process with moderate signs of activity. The ASTA was 5.6 to 10.0 units/ml, ESR 19 mm and white cell count $7,600/\text{mm}^3$ with 4,500 polymuclear and 3,300 mononuclear leukocytes and differential count 61% per cent eosinophils. Serum immunoglobulin electrophoresis normal, blood culture negative. Biopsy six months later of the proximal part of the tibial metaphysis revealed partially destroyed bone tissue with infiltration of plasma cells. Bacterial and TB cultures from the tissue were negative. Pharyngeal cultures and blood cultures were also negative. ASTA 2.0 units/ml. Mantoux 2 TU positive. Blood group O Rh (+). Isoagglutinin A antibody titre 1/60. Quantitative serum immunoglobulin assay disclosed an increased IgE con-



Fig. 4 a) Osteolytic foci bilaterally around the ischiopubic symphysis b) One year after the onset of the disease chronic osteomyelitic foci present in the left pubic bone adjacent to the symphysis. Regression of lesions in the bone around the right ischiopubic symphysis.

entration but normal concentrations of IgG, IgA and IgM. Eosinophils $288/\text{mm}^3$ blood. Direct and indirect Coomb tests were negative. Lupus erythematosus (LE) test also negative. No antinuclear factors in the serum could be detected. There were no serum antibodies directed against smooth muscle, cytoplasmic thyroid antigen, renal glomeruli or mitochondria.

A diagnosis of chronic symmetric osteomyelitis was made and a course of Klavocillin initiated. This had to be discontinued after 19 days, however, because of the development of general urticaria. Lincomycin was therefore substituted for a period of ten weeks. Since about this time the patient has been free from symptoms, apart from generalized urticaria which developed after taking an oral contrast medium for cholecystography and following local anaesthesia for dental treatment. No abnormalities of the joints have been evident at repeated clinical examinations up to the present time. The muscular atrophy in the right leg has regressed completely. The ESR, ASTA and serum electrophoresis as well as the roentgenographic findings have gradually become normal.

Severe allergic reactions to various substances prompted a recent examination and disclosed a raised serum concentration of IgE (870 units/ml), eosinophils $488/\text{mm}^3$ and positive intracutaneous tests to dog, cat, horse, cow and t. fish, house dust and birch pollen.

The patient has had periodic pain in the right side of the abdomen. Oral cholecystography and urography revealed nothing abnormal. A cyst of the right ovary was recently removed. There were no further abdominal symptoms after the operation.

Radiology

Right and left knees. On first admission symmetric roundish or columnar osteolytic lesions with thin surrounding zones of sclerosis were evident in the lower femoral and upper tibial metaphyses, not obviously invading the epiphyses (Fig. 1). Partial destruction of the cortex of the popliteal aspect of the right femoral metaphysis with periosteal reaction was evident (Fig. 2). One year

Later progressive changes with sclerosis and osteolytic foci were observed followed after another year by regression of the latter and an increase in the former.

Six years after the onset no osteolytic lesions persisted. The trabecular structure of the right knee had signs of repair and the medial part of the metaphyses adjacent to the epiphysis still exhibited an irregular appearance with a predominance of sclerosis. This was particularly evident in the left knee although some small osteolytic foci remained in the medial part of the metaphysis near the growth plate. The cortex overlying the lesion had a speckled appearance.

Seven years after the onset of the disease the roentgenologic appearances were entirely normal.

Right humerus (upper end) Partly coalescent osteolytic foci surrounded in part by sclerosis, in the proximal end of the metaphysis of the humerus with some erosion of the cortex (Fig. 3). Slight periosteal bone proliferation evident.

One and a half years after the onset the lesions had completely disappeared and the bone structure had been remodelled to the normal with no signs of previous derangement. At closure of the epiphyseal growth plate at the upper end of the humerus the metaphysis had a normal appearance.

Pelvis On admission small roundish osteolytic foci were present symmetrically in the rami adjacent to the xiphopubic synchondrosis with partial erosion of the cortex (Fig. 4 a). One year after the onset the lesion on the left side had become more extensive with osteolytic involvement, consisting of thickening and some sclerosis of the left symphyseal structures of the pubic bone (Fig. 4 b). A year later a reduction in the size of the osteolytic lesions occurred. The bone structure on the right side now appeared normal.

Six years after the onset all the lesions had disappeared.

Discussion

Subacute and chronic symmetric osteomyelitis is characterized roentgenologically by multiple osteolytic and sclerotic lesions in symmetrical bone metaphyses (Gronow et coll.). The distal femoral metaphyses and the proximal and distal tibial metaphyses as well as the sternal ends of the clavicles are particularly affected. The symptoms at onset are usually unilateral with lameness and swelling or tenderness over the metaphyseal region affected. Apart from occasional short episodes of fever generalized symptoms are unusual both initially and in the subsequent course of the disease. When untreated the disease may last for several years with intermittent symptoms. The laboratory findings are specific. The ESR is moderately elevated and the number of leukocytes in

the peripheral blood is normal or slightly raised. GLEDION *et coll* reported that biopsy material in three out of four instances revealed plasma cellular osteomyelitis; these 3 cases presented no evidence of bacterial growth.

The disease in the present case was considered initially to be one of juvenile osteochondroma. The subsequent course, however, with periodic symptoms mainly from the right knee, bilateral roentgenologic lesions in the metaphyses typical of chronic osteomyelitis, an ESR constantly elevated and a serum electrophoresis pattern compatible with a low grade process with immunoglobulin response was suggestive of chronic symmetric osteomyelitis (GLEDION *et coll*). A similarity appears to exist in the roentgenologic findings between the 4 cases described by these authors and the present case (GLEDION personal communication) as well as the close resemblance to a case of osteochondroma or low grade destructive osteomyelitis reported by CAFFEY (1967). The clinical course of the present case as well as the appearances and evolution of the roentgenologic findings resemble case I of GLEDION *et coll*. The two differ however in the localization of the bone lesions which in the present case was similar to that of cases II and III of GLEDION *et coll*. Osteolytic lesions in the proximal metaphysis of the humerus as in the present case were not evident in the previously reported cases of subacute or chronic osteomyelitis. The pelvic lesions in the present case resemble those of osteochondropathia ischio pubica, a disorder with a variety of possible pathogenetic factors (POSCHL 1971).

The pathogenesis in chronic symmetric osteomyelitis is not clear. Three of the 4 cases reported by GLEDION *et coll* had negative biopsy cultures which does not however exclude a bacterial origin; the biopsy culture of the fourth case in which the disease was subacute produced a growth of pneumococci.

The biopsy culture in the present case was negative, but the histology indicated a chronic inflammatory process; this may have represented staphylococcal osteomyelitis of low virulence. Supporting this possibility were the constant elevation of the ESR and ASTA titres before antibiotics were given as well as the rapid disappearance of the symptoms once this therapy had been instituted with a return to normal of the ASTA and ESR. The immunologic examination revealed no evidence of reduced cellular or humoral immunity suggestive of an infection disposing factor. GLEDION *et coll* postulated that chronic symmetric osteomyelitis might be an autoimmune disease of bone; laboratory examination revealed nothing to indicate autoimmune disease in the present case.

The diagnosis is based to a large extent on a proper evaluation of the radiographic findings in skeletal disease with vague clinical signs such as subacute and chronic symmetric osteomyelitis. It is possible for subacute and chronic osteomyelitis to pass unrecognized and to persist without a correct diagnosis and adequate treatment.

SUMMARY

A case of chronic symmetric osteomyelitis in a girl is reported. The clinical course and radiologic findings are described and discussed.

ZUSAMMENFASSUNG

Bericht über einen Fall von chronischer symmetrischer Osteomyelitis bei einem Mädchen. Die Beschreibung und Besprechung des klinischen Verlaufes und der Röntgenbefunde.

RÉSUMÉ

Présentation d'un cas d'ostéomyélite chronique symétrique chez une fille. Description et discussion de l'évolution clinique et des signes radiologiques.

REFERENCES

- Curry J. In: *Pediatric X-ray diagnosis*. Fifth edition. p. 67. Year Book Medical Publishers, Chicago, 1967.
- Gornow A. Personal communication (1971).
- Holthuisen W., Masel L. F. and Viscosa D. Subacute and chronic symmetrical osteomyelitis. *Ann Radiol* 15 (1972) 329.
- Pöschel M. Juvenile Osteo-Chondro Nekrosen. In: *Handbuch der medizinischen Radiologie*. Band 1/4 S. 152. Springer, Berlin Heidelberg New York 1971.

DENTAL ROOT FRACTURE DIAGNOSED BY POLYTOMOGRAPHY

M HÄVERLIND and G RANSTRÖM

Fractures of the dental roots usually do not provide difficulties of diagnosis being easily discovered at a conventional roentgen examination if they are not clinically revealed. However in rare cases the fracture may be thin or oriented in a plane running in craniocaudal or lingual buccal directions, and tomography is then required. The basic prerequisite for this type of examination is access to a tomograph unit with hypocycloid motion delivering thin cuts of high quality.

Case report

A woman aged 25 was kicked in the face by a horse. On clinical examination fractures were revealed in the crowns of the second and third teeth of the upper left jaw. Tooth number four was luxated. A fracture in the root of the fifth tooth was later suggested, the tooth being tender on percussion. Conventional roentgen examination two months after the accident revealed a minor deformity suggestive of a fracture of the root (Fig. 1). The fracture was demonstrated unequivocally



Fig. 1 A curved deformity of the root of the tooth suggesting fracture.

Fig. 2 The root fracture demonstrated by polytomography in both lingual buccal (left) and distal mesial (right) projections.

Fig. 1

Fig. 2

by tomography. Serial tomograms 0.5 mm apart were taken in straight lingual buccal and distal mesial projections (Fig. 2).

Discussion

It is not possible to examine a single isolated tooth in two perpendicular planes with the conventional roentgen technique since this does not allow a distal mesial projection. This means that a fracture running an oblique or a spiral course in a lingual buccal plane is not always discovered when directed craniocaudally. It is well known that the anatomy of exceedingly small structures of the human inner and middle ear may be analyzed by polytomography (MURPHY & FRIIS 1959; BRUNNER & BRAHE PEDERSEN 1971). The precision of this method is evidently such that even thin fractures in a tooth may be demonstrated.

SUMMARY

Tomography using hypocycloid motion for the diagnosis of dental root fracture not fully revealed at conventional roentgenography is described and the potential value of tomography for this purpose is emphasized.

ZUSAMMENFASSUNG

Die Tomographie unter Verwendung von Hypozykloiden Bewegung zur Diagnose einer nicht deutlich nachweisbaren Zahnwurzel Fraktur wird beschrieben und der mögliche Wert der Tomographie für diesen Zweck hervorgehoben.

RÉSUMÉ

Les auteurs décrivent la tomographie hypocyloïdale pour le diagnostic de fracture d'une racine dentaire qui n'avait pas été clairement mise en évidence par la radiographie ordinaire. L'insiste sur l'intérêt possible de la tomographie pour ce diagnostic.

REFERENCES

- BRUNNER S. and BRANK PEDERSEN CHR. Experimental roentgen examination of the vestibular aqueduct. *Acta radiol. Diagnosis* 11 (1971) 443.
- MUNDICH K. und FREY K. W. Das Röntgenschnittbild des Ohres (The tomogram of the ear). Georg Thieme Verlag Stuttgart 1959.

HIGH VOLTAGE RADIOGRAPHY

Theory and clinical application

S. REICHMANN and G. G. HELANDER

Efforts made a decade or more ago to adapt radiographic procedures to high voltage potentials (MATTSSON 1953) were not universally successful. Low voltage is still employed today in skeletal radiography as well as in examinations with iodine contrast media. Chest radiography at a tube potential of 200 kV was tried in the early 1960s in several Swedish centres, however only a few clinics still retain this technique (STRAND 1973). The only fields were those of barium sulphate examinations of the gastro-intestinal tract and gas myelography.

Nevertheless considerable advantages may be obtained with the high voltage technique provided one important matter can be solved. These consist of short exposure times, reduced tube load, short intervals between exposures and possibly reduced patient dose. The problem to be solved is complex. Broadly speaking it concerns impaired contrast and possible ways of improving it.

Radiography may now be considered from the aspect of two distinct categories: signals and noise (SCHÖNER 1962, ROHLER 1962, MORROW 1966). Signals constitute the information desired but noise is always objectionable. As with sound, noise disturbs the ability to perceive weak signals. Thus, image elements

Submitted for publication 14 August 1973.

of low contrast (low signal intensity) always stand the risk of being obscured by the noise to a degree as to become imperceptible.

Secondary radiation is one important type of noise, since it consists of radiation without any information about the object. However, even primary radiation may contain noise. One aspect of this latter noise is quantum mottle, which is due to the fact that primary radiation consists of discrete photons (= quanta). The image is formed by a limited number of such photons and their information is not evenly distributed over the film but varies randomly; this is due to the statistical chance of each photon being absorbed in the recording medium. The background tends thus to become irregularly blackened even in places where it should be completely homogeneous. Increased sensitivity generally gives rise to an image built up by a smaller number of photons, which means increased quantum mottle (= increased statistical chance of local variations in absorption). However, if the increase in sensitivity be due solely to an increased ability of the film or screen-film combination to absorb roentgen photons, the quantum mottle will not increase (REICHMANN 1974). To the quantum mottle is added structure mottle caused by the crystal structure of the intensifying screens. If this structure be inhomogeneous, the fluctuations in roentgen photon absorption will be larger than pure quantum mottle alone (CLEARE *et al.* 1962; REICHMANN & HELANDER 1974). This means that a coarse-grained screen will increase the tendency towards uneven background blackening. One purpose of the present report is to suggest that the graininess of the film is another significant type of noise.

A signal may be so weak as to become completely obscured by the noise, the latter being simply an overall term for undesired signals without information about the object. A well-known example prevents itself in the Bucky grid being removed during radiography of the abdomen: many details normally visible will then disappear completely and at the same time the image contrast will be reduced. A more hard-working film used in an attempt to counteract the impaired image quality will improve the signals and the noise to an equal degree (REICHMANN 1974) since noise also is a kind of signal. The details that became invisible will thus not reappear in the high-contrast image. The only adequate way out is to reduce the noise, i.e. to reinvert the Bucky grid. A similar analysis may be made for other types of noise as well, so that it may be generally stated that if image elements of very low contrast are to appear, the noise level should be lowered.

The signal intensity in high-voltage radiography is decreased due to decreased absorption differences in the object. Often the noise is also increased owing to an increase in the secondary radiation. This means an impaired signal/noise ratio and a loss of low-contrast detail, one that cannot be compensated for by

Table

Screens/film combinations used in the examination of a foetus specimen at 120 kV

Film/Screen	Super	X-omatic Regular
Corn RP	X	X
X-omatic General		X
Verichrome	X	X
Maxxray T3		X

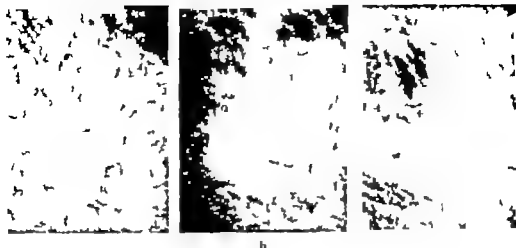
more hard working film. The quality loss is so severe as to preclude the present day use of high voltage radiography except when barium sulphate is used and the absorption difference is large enough to produce sufficient signals.

Secondary radiation is however only one type of noise. The question remains whether the impaired signal/noise ratio can be improved by means of a lowering of the other noise types. As regards structure mottle such a reduction may be obtained by using Kodak X-omatic screens (REICHMANN & HELANDER 1974). The quantum mottle may be brought to an appropriate level by changing the film sensitivity. The influence, if any, of film graininess on the total noise level must however still be determined. This factor has been dealt with and has led to the selection of a suitable screen/film combination: this has been tested in some clinical fields of low voltage examination (skeleton urography and cholecystography) mostly utilizing a tube potential of 120 kV.

Experimental

The first problem to be tackled concerned the noise inherent in the radiographic film. If the signal intensity be decreased then the threshold of the contrast perceptibility of the film should be as low as possible: if it be very low weak signals may be expected to appear in spite of their low intensities.

The perceptibility threshold of different radiographic films cannot be obtained with the films exposed in a cassette since the quantum mottle of the roentgen rays may then set the threshold higher than effected by one or more of the films. Likewise the films cannot be exposed directly to roentgen rays since the different energy contents of light photons and roentgen photons will give rise to an important source of error (BACKSTROM & LUNDIN 1959). A film intended for exposure to visible light should be tested by means of light: thus such films can not be tested by any form of radiography. The following method was chosen. It was assumed that the perceptibility threshold is correlated to the graininess of the film so that fine grain makes for a low threshold (fine grain = low noise i.e. a



b

Fig. 1 Films of femoral neck of matured specimen. 11 cm of water. Tube potential 120 kV. The screen/film combinations are: a) Siemens Saphir/Agfa Cervert Curix RP, b) Kodak X-omatic Regular/Kodak X-omatic General, c) Kodak X-omatic Regular/Agfa Cervert Medichrome N. The level is lowest in c).



b

Fig. 2 Films exposed at 120 kV: a) Hip joint (lateral projection) and b) fifth lumbar vertebra (lateral projection). 11 cm of water. The hip joint was markedly obese and had senile osteopenia. Richness of detail (bone texture).

favourable signal/noise ratio) An original image with very weak signals was produced in a low sensitive film with a fine grain—Kodak Kodalith Ortho type III This original image was copied onto the roentgen films to be tested by means of ordinary photographic contact copying The following films were tested: Kodak RP/R, Agfa/Gevaert Curix RP, Kodak X-omatic High and X-omatic General, Kodak RP/F X-omat Fluorospot, Agfa/Gevaert Medichrome and Agfa/Gevaert Mamoray T3 The first five films are 90 second films, the last of them being intended for the 70 mm camera; they were developed in a 90 second roll machine The Medichrome film was developed by a 20 minute process in a roll machine The Mamoray film has a low sensitive industrial emulsion with a high silver content; it was developed by a 6 minute process in a roll machine (cf. DECHEREAU *et coll.* 1974)

The 90 second emulsions all produced impaired rendering of such detail in the original image as was faint but still visible The Kodak X-omatic General film produced somewhat better recording than the other films in this group its acuity also being the lowest of the double emulsion 90 second films The impaired recording occurred despite the fact that the general contrast was greater in the roentgen film than in the original image The industrial film rendered clearly even signals that were only just visible in the original image The Medichrome film did not have the same low perceptibility threshold as the industrial film; however properly exposed, the films were not very different The maximum capacity of the Medichrome film was reached only when the film was inspected through a red filter The difference in detail rendering between the films is not reproduced in the present report owing to technical difficulties

The grain size of all emulsions was examined by microscopy The 90 second emulsions were similar although the X-omatic General film had a somewhat finer grain Medichrome film (after black and white development to produce the silver grains that precede the colour grains) and the Mamoray T3 turned out to have significantly finer grain without any great difference between them

One important conclusion may be drawn from these tests The ultimate threshold of perceptibility in radiography is seldom determined by the visual organ since everyday roentgen films may display a noise that sets the threshold at a significantly higher level A prerequisite of high voltage radiography is a film that can reproduce signals down to the threshold of human perceptibility

The second phantom test series was based on radiography of a macerated femur bathed in water The bone lay in a plastic basin under a water level of 11 cm and radiography was performed at 120 kV Two types of intensifying screens were used: Siemens Saphir (high structure mottle) and Kodak X-omatic Regular (low structure mottle) Most of the films presented in the first phantom test were included The screen-film combinations are listed in the Table The



Fig. 3a



Fig. 3b



Fig. 4

Fig. 3 Urogram recorded at 120 kV a) after a normal dose of contrast medium and b) after 5 times of normal dose

Fig. 4 Cholecystogram recorded at 90 kV. Normally concentrating gallbladder with stones

results confirmed the film test described above as well as the screen investigations presented earlier (REICHMANN & HELANDER 1974). The screens with high structure mottle give rise to useless images regardless of film (Fig. 1 a) while those with low structure mottle produced acceptable results. Medichrome film had a slight but definite advantage compared with the 90 second black and white film (Fig. 1 b and c). The best image was obtained with X-omatic screens and Mamomat T3 film. However, no great difference existed between this film and the Medichrome film when the latter was correctly exposed.

Clinical application

Since the image quality of the femur was regarded as acceptable at 120 kV with X-omatic screens in conjunction with Medichrome film, this combination was given a preliminary test in clinical examinations. Three types of examination were chosen: skeleton of the trunk, urography and cholecystography. A tube potential of 60 to 80 kV with Siemens Saphir screens and Curix RP film is in routine use today. This technique was used as a reference technique, so that all the patients were examined in the same way. One or more double exposures were made: image pairs were thus produced, one image being obtained with the reference technique and the other with the high voltage technique. A tube potential of 120 kV was the rule throughout in the high voltage system in the



Fig. 5 Chest roentgenogram recorded 150 kV. The richness in detail suggests that higher tube potentials may be useful.

urography and skeletal examinations. In cholecystography various potentials between 80 and 120 kV were tested; most recordings were made at 90 kV. Chest films were also occasionally obtained at 150 kV as compared with 120 kV for the reference system. Forty-eight image pairs were obtained from the same number of patients in the skeletal examinations while 17 image pairs were taken, one from each patient in the urographies. The number of cholecystographic images was 57 in 16 patients. The patients were adults and some were aged.

The test results were promising (Figs 2—5). The structure of trabecular bone stood out amazingly well even in obese patients with senile osteoporosis (Fig. 2). As against the low voltage reference technique no information was lost in the skeletal images. However one important condition was the correct exposure of the high voltage films: with this exposure incorrect information was lost. A small degree of under exposure was especially unfortunate since this produced a false impression of it being adequate. The high voltage image was somewhat under exposed in a patient with pulmonary metastases from mammary carcinoma: the vertebral changes might have been overlooked if the under exposure had been unrecognized.

The contrast filled renal pelvis, ureters and bladder stood out well in urography (Fig. 3). In one patient only 25 per cent of the normal dose of medium could be injected owing to severe urticaria reaction: an acceptable film was obtained with the high voltage technique (Fig. 3 b). The renal outline was often difficult to follow when high voltage was employed: a low voltage technique should probably be used for the demonstration of kidney shape and calcifications before the injection of contrast medium.

A gallbladder with an ordinary contrast filling was adequately depicted even at 120 kV. Excellent recording appeared always to occur at 90 kV except in those with an extremely low concentration of contrast medium (Fig. 4).

The chest films obtained were exceptionally good (Fig. 5). Possibly even higher voltages may be useful in this type of examination.

One general impression gained from the high voltage technique was that several structures could be superimposed without much disturbing effect. (Of the iliac bones and the lumbar vertebra in Fig. 2 b.)

Discussion

The present investigation indicated that a high voltage technique may be useful to a greater degree than is realized today if noise reduction be undertaken: the noise to be attacked is inherent in the film and the intensifying screens. The most useful screen film combination of those tested appeared to be Kodak X-omatic Regular screens with Agfa/Gevaert Medichrome film.

Medichrome film is a blue colour film that demands special viewing conditions. In white light the film tones vary between white and deep blue and the contrast is low. However, since the noise level is low the low contrast blue image contains information not readily accessible to the unaided eye. If the film be inspected through a yellow filter the tones of the film will vary from yellow to green, the film thus becoming bi-coloured. Contrast is markedly increased in this way. Still more information may be obtained by means of a red filter: the tones of the film then vary from red to black with extremely high contrast.

Some insights were gained as to the viewing of high voltage images. The yellow filter proved to be of great value for ordinary inspection. This could well be done under conventional viewing conditions, strong light being usually unnecessary. The red filter caused more loss of light and inspection at a distance was then impaired. However, the red filter could be mounted into the viewer constructed by MATTHESON (1952). Inspection could then usually be carried out without an abnormally strong light source. The presence of the yellow filter did not interfere when the films were inspected through the red filter. Thus a good technical solution of the filter problem was based on the permanent presence of a yellow

filter in the light box so that all roentgenograms were given the basic increase of contrast afforded. Details could be inspected more closely with a Mattson viewer fitted with a red filter. It was repeatedly found that conventional black and white roentgenograms could easily be inspected by means of the light box with a yellow light. The subjective contrast did not suffer and with adequate exposure the films were not too dark.

SUMMARY

A high voltage technique seems to be more useful than is generally believed provided certain precautions are taken. A theory on the nature of such precautions is presented and discussed. Some clinical applications are described.

ZUSAMMENFASSUNG

Die Hochvolt Technik scheint am endbarer als allgemein angenommen zu sein unter der Voraussetzung dass gewisse Vorsichtsmaßnahmen angenommen werden. Eine Theorie über die Art derartiger Vorsichtsmaßnahmen wird gegeben und diskutiert. Einige klinische Anwendungen werden beschrieben.

RÉSUMÉ

Une technique d haute voltage paraît plus utile qu'on ne le croit généralement, condition de prendre certaines précautions. Les auteurs présentent et examinent une théorie sur la nature de ces précautions. Ils décrivent quelques applications cliniques.

REFERENCES

- BACKSTROM H. och LUNDIN A. Det roentgenografiska materialet och dess behandling. I Fotografiskt handbok. (In Swedish.) Edited by H. Backstrom. Natur och Kultur, Stockholm, 1959.
- CLARK H. M., SPLETSTROM H. R. and SERMAN H. E. An experimental study of the mottle produced by X-ray intensifying screens. *Amer. J. Roentgenol.* 88 (1962) 168.
- DEMOCHAK E., REICHMANN S. and BLUM M. Film quality in mammary radiography. *Acta radiol. Diagnost.* 15 (1974) 95.
- MATTSON O. Aspects of the interpretation of contrast and detail in radiographs. *Acta radiol.* 38 (1952) 477.
- Practical photographic problems in radiography. With special reference to high voltage technique. *Acta radiol.* (1955) Suppl. X, 120.
- MORGAN R. H. Visual perception: fluoroscopy and radiography. *Radiology* 86 (1966) 403.
- REICHMANN S. Efficiency of intensifying films, screens. To be published in *Acta radiol. Diagnost.*
- and HELANDER C. G. Homogeneity of intensifying screens. To be published in *Acta radiol. Diagnost.*
- ROHLER R. Informations-theoretische Röntgenologie. *Ärzt. Forsch.* 18 (1962) 108.
- SCHÖNER H. Anwendbarkeit der Informations-theorie auf Probleme der Röntgendiagnostik. *Ärzt. Forsch.* 16 (1962) 10.
- STRAND T. Personal communication. 1973.

ANGLE DISTORTION IN NARROW BEAM ROTATION RADIOGRAPHY

KJELL ARNE SANFORS and ULF WFLANDER

A panoramic image produced with a rotating narrow beam system is made up of two central projections acting simultaneously. One of these projections has the rotation centre as an imaginary focus and determines the horizontal dimensions of the image and the other has the tube target as its focus and gives the vertical dimensions; the latter projection furthermore produces blurring in the horizontal plane of the image (WFLANDER & NYSTROM 1971, 1974; WFLANDER 1974). The fact that different projections determine the dimensions in the horizontal and vertical directions results in a disproportionality between the length and height measurements of the image, so that the slope of obliquely positioned details in the object will be depicted incorrectly. The combined effect of different horizontal and vertical dimensions in an image exposed with a rotating narrow beam method may therefore be described as angle distortion.

The distortion in the images obtained with an Orthopantomograph has been analysed experimentally by SCHOPF (1966), LANGLAND (1968) and HEDD (1971). The geometrical proportions of the image in both horizontal and vertical directions were calculated mathematically by LAMMIALO (1964) but his mathematical expression for the horizontal dimensions of the image is not quite

correct in so far as the magnitude of the blurring has an effect on the length of a calculated distance in the image. The combined distortion due to differing proportionality in the image in the horizontal and vertical directions—angle distortion—does not seem to have been analysed mathematically previously.

The mathematical expressions were deduced using the model for narrow beam rotation methods presented by WELANDER (1974).

Angle distortion

In the horizontal plane the length of the image is directly proportional to the ratio of the velocity of the film to the velocity of the beam in the object

$$d_i = \frac{d_o R \omega_f}{r \omega_o}$$

where d_i is the length of the image, d_o the length of the object, R the radius of the film, ω_f the angular velocity of the film, r the radius of the object and ω_o the angular velocity of the beam in the object.

If the radius of the object r is given an increment Δr the length of the image will be

$$d_i = \frac{d_o R \omega_f}{(r + \Delta r) \omega_o} \quad (1)$$

From this expression the horizontal dimensions of the image are obtained (Fig. 1).

In the vertical plane the height of the exposed image is directly proportional to the ratio of the target film distance to the target object distance

$$h_i = \frac{h_o A}{D}$$

where h_i is the height of the image, h_o the height of the object, A the target film distance and D the target-object distance.

If the radius of the object is given an increment Δr the target-object distance receives the same increment and the height of the image when the radius of the object varies will be

$$h_i = \frac{h_o A}{D + \Delta r} \quad (2)$$

From this expression the vertical dimensions of the image are obtained (Fig. 1).

ANGLE DISTORTION IN NARROW BEAM ROTATION RADIOGRAPHY

KJELL ARNE SAMFORS and ULF WELANDER

A panoramic image produced with a rotating narrow beam system is made up of two central projections acting simultaneously. One of these projections has the rotation centre as an imaginary focus, and determines the horizontal dimensions of the image, and the other has the tube target as its focus and gives the vertical dimensions; the latter projection furthermore produces blurring in the horizontal plane of the image (WELANDER & NYSTROM 1971, 1974; WELANDER 1974). The fact that different projections determine the dimensions in the horizontal and vertical directions results in a disproportionality between the length and height measurements of the image, so that the slope of obliquely positioned details in the object will be depicted incorrectly. The combined effect of different horizontal and vertical dimensions in an image exposed with a rotating narrow beam method may therefore be described as angle distortion.

The distortion in the images obtained with an Orthopantomograph has been analysed experimentally by SCHOFF (1966), LANGLAND (1968) and HEDIN (1971). The geometrical proportions of the image in both horizontal and vertical directions were calculated mathematically by TAMMISALO (1964), but his mathematical expression for the horizontal dimensions of the image is not quite

Submitted for publication 30 August 1973

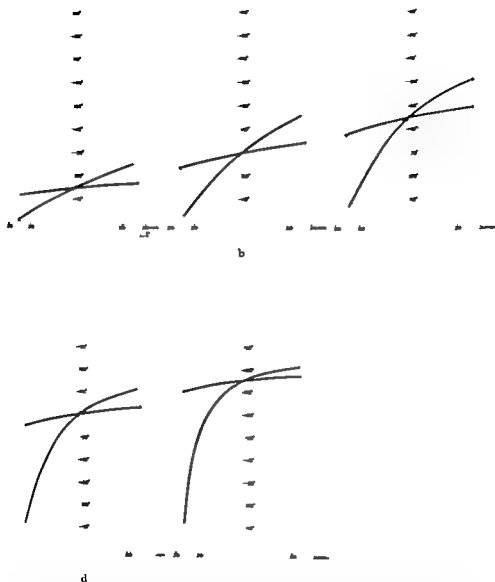


Fig. 5. The angle of inclination α of structural detail in relation to the horizontal plane in the image as a function of an increment Δr to the radius of the object. The values are calculated for the interior rotation centre $r = 98$ mm (—) and mean value of the effective projection radius in the lateral rotation centre $r = 96$ mm (---) in the Orthopan tomograph 3.1. The continuous transition between the rotation centres occurs continually in the interval between the functions. The angle of inclination for the real shape of the structural detail in the object is 1° in (a), 30° in (b), 45° in (c), 60° in (d) and 75° in (e). The angles of the object are correctly depicted in the sharply depicted object plane. Angle distortion occurs outside this plane.



b

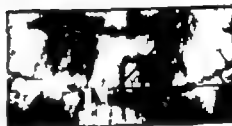


Fig 3 Effect of angle distortion in roentgen images produced with narrow rotating beam
 a) The position of the object agrees satisfactorily with the sharply depicted object plane b) The object is positioned in front of the sharply depicted object plane. The angle made by structural detail with the horizontal plane is increased c) The object is positioned behind the sharply depicted object plane. The angle made by structural detail is reduced

Equation (3) or the simplified expression equation (4) may be used to calculate the combined effect of the horizontal and vertical dimensions of the image—the angle distortion—in rotating narrow beam methods. For object parts with slopes of 15 30 45 60 and 75 in relation to the horizontal plane $\frac{h_0}{d_0}$ is 0.2679 0.5774 1 1.732 and 3.732 respectively. With the values for object radius and for the target film and target object distances that apply in the Ortho pantomograph 3 the functions illustrated in Fig. 2 will be obtained.

Discussion

The functions (Fig. 2) illustrate the angle distortion of an object without thickness, when it is displaced in relation to the centre of the object plane de-

pected without blurring by a rotating narrow beam method. The functions also illustrate the effect of angle distortion in an object with thickness.

The magnification factor at the centre of the object plane depicted without blurring is the same in both horizontal and vertical directions. There is thus no distortion at the centre of this plane, but the image is magnified; the magnification factor is the same irrespective of the object radius. However, even small increments to the object radius cause angle distortion to arise in the image. The distortion is greatest when the radii are small and is most marked for structural details in the object that form a large angle with the horizontal plane, for example obliquely positioned non-erupted teeth.

The angle distortion arising in connection with narrow beam rotation methods is such that the positioning of the object in the equipment may be regarded as critical. The slope of the teeth in the image is influenced by their position in relation to that part of the object which is depicted without blurring: a tooth lying in front of the centre of the sharply depicted object plane will have in the image a seemingly increased angle in relation to the horizontal plane, while for a tooth lying behind the sharply depicted plane the angle will appear reduced (Fig. 3). It is obvious that since the teeth slope not only in a mesial-distal but also in a buccal-lingual direction the angle distortion in the image may be considerable.

In panoramic views of the teeth and jaws produced with a narrow beam rotation method the distortion in areas outside the centre of the sharply depicted object plane is such that the true slope of any particular detail is hard to assess correctly.

SUMMARY

The distortion of a panorama roentgen image of the teeth and jaws exposed with rotating narrow beams depends on differing proportionality in the image in the horizontal and vertical planes. This distortion may be defined as angle distortion and has the effect that obliquely positioned structural details in the object will be depicted with a false angulation in the image. The angle distortion has been calculated mathematically. Outside the sharply depicted object plane angle distortion may be considerable and is greatest when the projection radii are small and most marked for structural details in the object that form a large angle with the horizontal plane.

ZUSAMMENFASSUNG

Die Distorsion eines Panorama Röntgenbildes der Zähne und Kiefer exponiert mit einem rotierenden schmalen Strahl hängt von der unterschiedlichen Proportionalität der horizontalen und vertikalen Ebenen im Bild ab. Diese Distorsion lässt sich als Winkeldistorsion definieren und hat zur Folge dass die schräg gestellten strukturellen Einzelheiten des

Review of the literature

In anatomic literature the intraorbital veins are described in detail (SZESZMAN 1869 GURWITSCH 1883 HENRY 1959). This information is not directly applicable to orbital phlebography however as the veins usually demonstrated at phlebography cannot be anatomically distinguished from veins that are not significant phlebographically. The anatomic presentations have often been arranged with the surgical approach to the orbit in mind and comparison with the phlebographic appearance is difficult for this reason also. Angiography of anatomic specimens of the orbits have been made by SALAMON *et coll.* (1972) who described briefly three main ophthalmic veins (one superior one middle and one inferior) connected by collaterals, but gave no information about the frequency of the different veins or their variations.

In the literature on orbital phlebography interest has been focused almost exclusively on the superior ophthalmic vein information concerning other intraorbital veins is scanty. BOUDET (1953 1955) and AROY ROSA *et coll.* (1967) stated that the inferior ophthalmic vein was narrow and that it filled rarely and then incompletely through small vertical collaterals. HANAFEE (1972) declared that this vein was only inconsistently filled and was not closely related to vital structures. A narrow inferior ophthalmic vein was observed by LOUVAARD & PASSENI (1968) in 13 out of 27 normal cases. More detailed results were reported by VIGNAUD (1970) who in a material of 20 patients managed to fill the inferior ophthalmic vein in 19 cases collateral veins in 19 the lacrimal vein in 12 and veins of the second order in 11 cases. No further analysis of the findings was given.

Present investigation

A detailed description of the technique used has been given previously (BRISMAR 1974 a) and is therefore not repeated here.

The analysis of the small orbital veins is based on the same phlebographic material of 60 patients used in previous reports on the phlebographic technique and on the anatomy of the superior ophthalmic vein (BRISMAR 1974 a, b). The material suitable for a detailed analysis of the intraorbital venous anatomy consisted of 57 orbits arranged into two groups: 38 orbits in 32 patients with normal cavernous sinuses as well (group N) and 19 orbits in 10 patients with an intra- or parasellar expansive lesion but with no obstruction of the flow of contrast medium through the cavernous sinuses (group S).

Results

Nomenclature

It was necessary to supplement the existing nomenclature as several of the intraorbital veins presented in this report have not previously been identified at

ORBITAL PHLEBOGRAPHY III Topography of intraorbital veins

JAN BRISMAR

The value of orbital phlebography in cases with unilateral proptosis is well established (e.g. LOMBARDI & PASSERINI 1969; LLOYD 1970; HANAFER 1972; HAYE et coll. 1970; BOUDRY 1955; ARON ROSA et coll. 1966). The diagnosis of a lesion is based mainly on changes in the superior ophthalmic vein. Displacement of this vessel will indicate not only the presence of an expansive lesion but also its location (e.g. SCHÖBER & BENDER 1968; HAYE et coll. 1970). In cases of major displacement of this vein few diagnostic problems exist but when there is only a small difference between the location of the vein in the two orbits the diagnosis of tumor is hazardous because a significant asymmetry between the two sides may be a normal condition (BRISMAR 1974 b). Since even small orbital veins are almost constantly demonstrated by the use of the present author's technique (BRISMAR 1974 a) it seemed reasonable to aim at a more certain diagnosis by also analyzing possible displacements of these veins. A prerequisite then is a deeper knowledge of the normal phlebographic appearance of these veins and their variations than is available at present. In the past this aspect has not gained much attention in reports on orbital phlebography.

From the Section on Neuroradiology, Director S. Cronqvist, Department of Diagnostic Radiology (Director Prof. O. Olsson), University Hospital S-221 83 Lund, Sweden. Submitted for publication 21 December 1973.

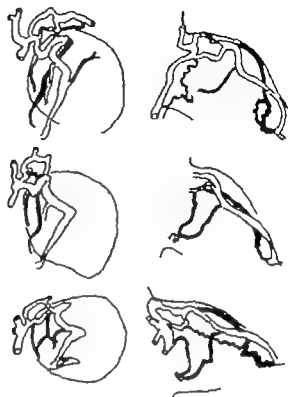


FIG. 2. The medial ophthalmic vein. Tracings in palpebral and lateral views of three orbits. Bottom: A palpebral medial vein.

In addition to the two tributaries (BRISMAR 1974 b) to the superior ophthalmic vein and to the posterior parts of the ophthalmic veins three types of anastomoses between the intra- and extraorbital veins were identified. They have been designated anterior, lateral and inferior extraorbital anastomosing veins.

Comparison between groups V and S. The frequency of filling of the different veins was analyzed separately for the groups N and S without any significant difference between the two groups being found (Table 1) nor was there any interindividual difference in the appearance of the superior ophthalmic vein between similar groups (BRISMAR 1974 b). These groups will therefore be discussed as one entity.

Superior ophthalmic vein. This vein can always be demonstrated in normal cases with an adequate phlebographic technique (Fig. 1). Its appearance has been described earlier (BRISMAR 1974 b) and will not be discussed further in this report.

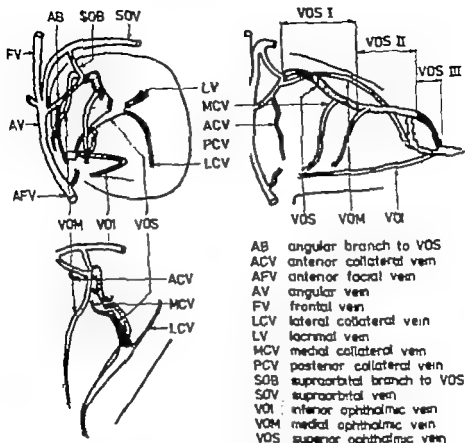


Fig 1 Suggested nomenclature of the intraorbital veins in lateral and medial views

phlebography. Intraorbital collaterals have been treated largely as an entity (BOUDET 1953; OFFRET & ARON-ROA 1965; HAYK et al. 1970) although sometimes separated into medial and lateral collateral veins (LOMBARDI & PASSENI 1968). In the present material four collateral veins were frequently found all directly connected to the superior ophthalmic vein and sometimes also to the inferior ophthalmic vein. They all had a course essentially from the floor to the roof of the orbit. These veins were named the anterior, posterior, medial and lateral collateral veins with respect to their positions in the orbit. The designation medial ophthalmic vein was reserved for a vein running from the anterior part of the orbit backwards to the cavernous sinus. A schematic representation of the phlebographic appearance of the intraorbital veins and the suggested nomenclature is given in Fig 1.



FIG. 5. Bilateral medial ophthalmic veins (→) largely superotemporal on the upper ophthalmic vein in the lateral view. b)

most cases exceeded 1.0 mm although in 13 cases it was less than 0.8 mm. GURWITSCH reported that in one third of his cases, no true inferior ophthalmic vein could be identified but that the function of the vein was taken over by a medial collateral vein.

The inferior ophthalmic vein usually (20 orbits) originated at the anterior medial part of the orbital floor from a venous rete anatomically described by SKRZYMAN and GURWITSCH. This rete is formed by the anterior collateral vein and in most cases also by the medial collateral vein. It may be connected with the lateral collateral vein and most often sends a thin anastomosis across the inferior orbital ridge to the anterior facial vein (Fig. 4). From this rete the inferior ophthalmic vein runs in a medially open curve in most cases close to the orbital floor situated on the surface of the inferior rectus muscle (GURWITSCH) and leaves the orbit through the inferior part of the superior orbital fissure below annulus tendineus communis. In three of the cases where the inferior ophthalmic vein was observed to originate in this rete, it was also connected with the medial collateral vein and in one case with the lateral collateral vein. In 9 orbits the

Tabl 1

Intraorbital veins in the groups N (normal orbit and no venous mass) and S (normal orbit possible periorbital or periorbital disorder) NOS = superior NOM = medial and NOI = inferior ophthalmic veins ACI = anterior VICI = medial LCI = lateral and PCI = posterior collateral veins LI = lacrimal vein

	N n = 38		S n = 10		N + S n = 57	
	n		n		n	
NOS	58	100	19	100	57	100
NOM	18	47	4	21	22	39
NOI	26	68	11	58	37	65
ACI	55	92	17	89	5	91
VIC	56	95	19	100	55	97
LCI	30	79	11	58	41	79
PCI	8	21	3	16	11	19
LI	28	74	1	79	43	7

Medial ophthalmic vein A medial orbital vein with a characteristic course was found in 22 out of 57 orbits (39 per cent) (Figs 2 3 4). This vein probably corresponds to a vein found by GURWITSCH in 3 of 42 orbits but has not previously been described at phlebography. It originates in either the angular tributary to the superior ophthalmic vein or in its anterior segment. It follows the orbital roof backwards close to the medial orbital wall and descends in the posterior part of the orbit to enter the cavernous sinus below the superior ophthalmic vein.

The medial ophthalmic vein in most cases had a diameter of 1 to 2 mm and was most easily recognized in an axial view. In the a p view it may be obscured by the anterior or medial collateral veins in the lateral view by the superior ophthalmic vein. In the posterior part of the orbit where the vein passes down on the medial side of the muscular cone it seems to be compressed from side to side and appears very narrow in the a p view but broad and often irregular in the lateral view.

In two orbits another medial vein was seen, with a different course. It ran straight from the angular tributary backwards to the cavernous sinus along the medial orbital wall. In one of these cases the medial ophthalmic vein could also be identified (Fig 2 bottom).

Inferior ophthalmic vein An inferior ophthalmic vein was observed in 37 out of 57 orbits (65 per cent). In the additional cases only a short posterior part of the vein could be identified. The diameter of the inferior ophthalmic vein in

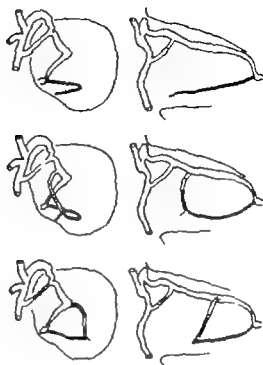


Fig 5 Inferior orbital foramen without connection to the collateral veins (16/37 orbits 43%) (top) or converted to the medial (12/37 orbits 32%) (middle) or to the lateral (8/37 orbits 22%) (bottom) collateral veins

inferior orbital foramen originated from the medial and in 7 from the lateral collateral vein (Fig 5)

An anastomosis between the inferior orbital foramen and the pterygoid plexus through the inferior orbital fissure was found by GURWITZ in 43 per cent of his material. This anastomosis occurred in 14 cases in the present material. In one of these cases no connection was observed between the inferior orbital foramen and the collateral veins or the rete. In one case (not included in the material of 57 orbits) this communication was wide and constituted a direct continuation of the inferior orbital foramen (Fig 4). One similar case was illustrated in the report of SESEMAN.

Double inferior orbital foramina were present in 7 orbits. One vein had the normal course close to the orbital floor, the other was localized higher up in the orbit but otherwise had a similar course (Fig 6). This second vein probably corresponds to the *veine ophtalmique moyenne* mentioned by HENRI (1959).

Anterior collateral vein. A slender vein passing along the anterior part of the medial orbital wall from the angular branch of the superior orbital foramen to the rete in the anterior medial part of the orbital floor was demonstrated in 5/2

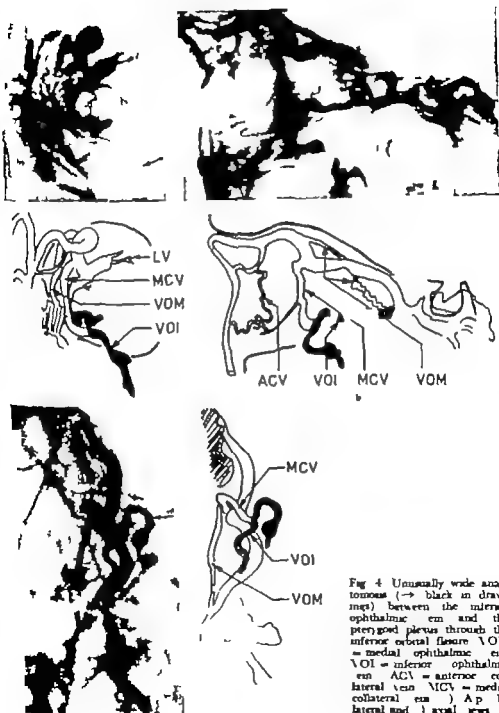


Fig 4 Unusually wide anastomoses (→ black in drawings) between the inferior orbital foramen and the pterygoid plexus through the inferior orbital foramen. VOM = medial orbital foramen. VOI = inferior orbital foramen. ACV = anterior collateral venous. MCV = medial collateral venous. a) lateral and b) sagittal views.

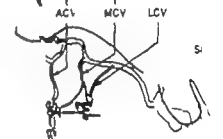
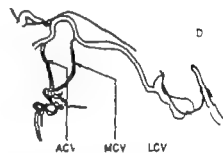
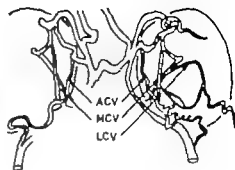


FIG. 7. Lateral collateral vein on the right side continuing directly down through the rete to the anterior facial vein. Lateral branch to the lateral collateral vein from extraocular facial vein on the left side (\rightarrow). a) Ap, b) straight lateral and c) oblique lateral course.

Lateral collateral vein. The lateral collateral vein was demonstrated in 41 out of 57 orbits (72 per cent) in 7 only for a short distance. In the remaining 34 orbits the vein could be followed down to the anterior lateral part of the orbital floor. It ran in a wide curve open medially and inferiorly, passing on the lateral side of the muscular cone, and joined the middle segment of the superior orbital vein.



Fig. 6 Bilateral double inferior ophthalmic veins (→) a) Ap and b) straight lateral view. c) Drawing from oblique lateral view. Left full drawn, right interrupted line.

of 57 orbits (91 per cent) (Figs 4-7, 8). The vein often anastomosed with the angular vein through narrow channels. In some cases the anterior collateral vein continued directly through the rete over the inferior orbital ridge to anastomose with the anterior facial vein (Fig. 7). The diameter of the anterior collateral vein was most often about 0.6 mm but could be considerably wider (Fig. 7).

Medial collateral vein. The medial collateral vein was demonstrated in 55 out of 57 orbits (97 per cent) in 50 completely, in 5 only fragmentarily. This vein (already described by GURWITZCH) after having passed superiorly and slightly backwards on the medial side of the muscular cone bends laterally to join the superior ophthalmic vein under the superior rectus muscle.

The vein was demonstrated down to the rete in 49 cases. In 13 of these it also gave off branches laterally below the muscular cone to communicate with the inferior ophthalmic vein. In one case it was connected only to the inferior ophthalmic vein. A schematic presentation of the different types of ramification of the medial collateral vein is presented in Fig. 9.

The medial collateral vein was doubled in five orbits. In three cases the branches from the rete and from the inferior ophthalmic vein were connected separately to the superior ophthalmic vein while in two cases paired branches left the rete (Fig. 10).

The medial collateral vein is usually the largest of the collateral veins and its diameter may equal that of the superior ophthalmic vein. In cases of occlusion of the latter the medial collateral vein must not be mistaken for a patent superior ophthalmic vein.

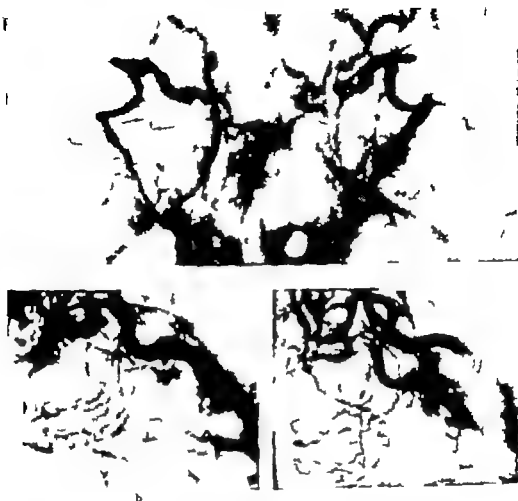


Fig. 10 Roent double medial collateral veins due to the ret. (→) a) Ap b) straight lateral and c) oblique lateral view

smooth curve directly down to the retina (Fig. 11 bottom). Nothing suggests that this course was caused by an intraorbital disorder. A schematic presentation of the different types of ramifications of the lateral collateral vein is given in Fig. 11.

Posterior collateral vein. A vein originating from the posterior end of the midsegment of the superior ophthalmic vein was present in 11 out of 57 orbits (19 per cent). Thus the posterior collateral vein, in most cases turned forwards laterally and downwards probably to pass around the muscular cone and then backwards to the cavernous sinus (Figs 1-12). In the lateral view this vein like

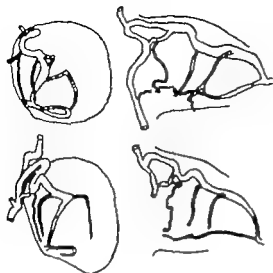


Fig 8 Anterior collateral veins (filled) in two orbits: p and lateral drawings



Fig 9 Medial collateral vein running directly from the rete to the superior ophthalmic vein (top) (36/50 orbits 7%) connected to the inferior ophthalmic vein by lateral branch (14/50 orbits 28%) (bottom)

The lateral collateral vein communicated with the inferior ophthalmic vein in 11 orbits. In four of these it also received a lateral branch and in one case a branch from the rete. No connection between the lateral collateral vein and the inferior ophthalmic vein could be observed in 23 orbits. The lateral collateral vein received a branch from the rete in 5 of these cases and in 2 also a lateral branch.

In the total material (60 patients: orbital disorders and incomplete examinations included) the lateral collateral vein had a different course in three orbits. The vein did not run to the frontal latero-basal corner of the orbit but in a

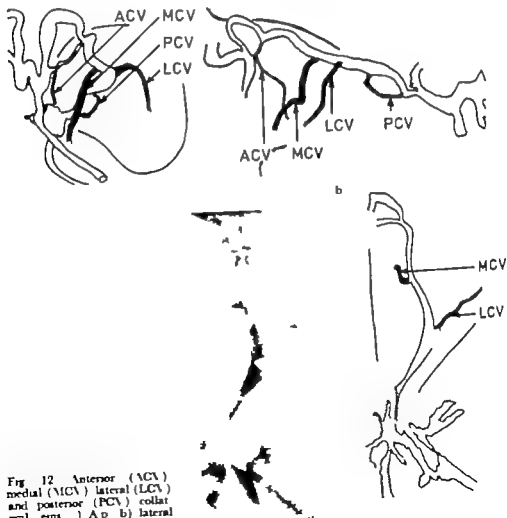


Fig. 12 Anterior (ACV) medial (MCV) lateral (LCV) and posterior (PCV) collateral veins. a) Ap b) lateral and c) ventral view.

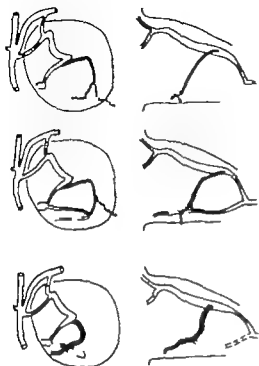


Fig 11 Lateral collateral vein running to the inferior lateral anastomosis part of the orbit possibly together with branches from the rete or from lateral extra orbital veins but not connected to the inferior ophthalmic vein (23/34 orbits 68%) (top) Communicating with the inferior ophthalmic vein (11/34 orbits 32%) (middle) Different course directly down towards the rete (in three cases not included in the normal material) (bottom)

The medial ophthalmic vein had an irregular outline. In the total material of 120 orbits it occurred in 19 orbits bilaterally in 7 patients (14 orbits). In three of the remaining five patients with a unilateral posterior collateral vein a medial ophthalmic vein was present on the other side.

Lacrimal vein. The lacrimal vein could be identified in 43 out of 57 orbits (75 per cent) in most cases only its posterior part. It joined the midsegment of the superior ophthalmic vein as one or several branches (Figs 1-4) but was in several cases connected instead to the posterior part of the lateral collateral vein. These results agree with those of GUERINACH. The sphenoparietal sinus (BENJAMIN 1974 c) is easily mistaken for the lacrimal vein in an a.p. view. In the axial view however separation of the two veins is easy.

Anastomoses between the extra- and intraorbital veins

Besides the supraorbital and anastomoses to the superior ophthalmic veins and the connections between the posterior parts of the ophthalmic veins and the cavernous sinuses several communications between the intra- and extra-

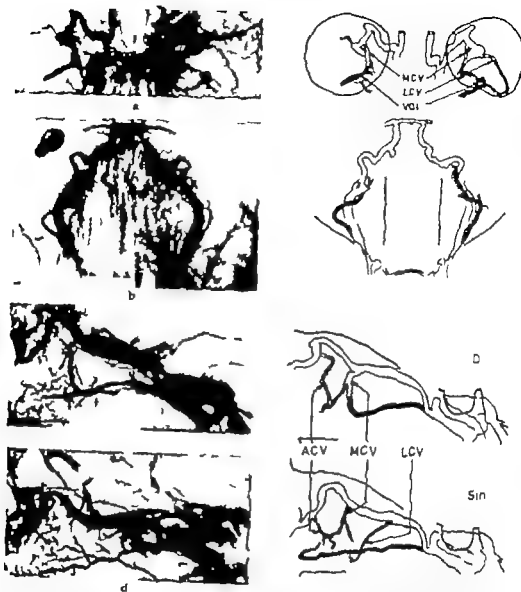


Fig 13 Inferior ophthalmic vein (VOI) Right side The vein originates from the medial collateral vein (MCV) which in another branch is connected to the retina. Left side The vein runs normal course from the retina but also communicates with the lateral collateral vein (LCV). Anterior collateral veins (ACV) bilaterally. a) Ap b) nasal od c) lateral view d) lateral view

makes it easy to confuse with a displaced superior ophthalmic vein in cases with occlusion of the latter.

Double inferior ophthalmic veins occurred in about ten per cent of the orbits one vein located close to the orbital floor and one with a similar course but

Table 2

Connections between the intra- and extraorbital veins in the groups N (normal orbit and cavernous sinuses) and S (normal orbit possible or proved intra- or parasellar disorder) AE 1 = anterior LE 1 = lateral and IE 1 = inferior extraorbital anastomosis

	N = 30		S = 19		N + S = 7	
			n			
AEA	18	47	8	42	6	46
LEA	3	8	7	37	10	18
IEA	9	24	5	26	14	2

orbital veins exist (SESEMAN GURWITSCH). In the present material such additional communications existed in 35 out of 57 orbits (Table 2).

Anterior extraorbital anastomosing vein. A connection between the rete and the anterior facial vein was found in 26 out of 57 orbits (Figs 2-4-7). As the routine phlebographic procedure includes compression over the place where this connection enters the anterior facial vein, the actual incidence is probably much higher.

Lateral extraorbital anastomosing vein. Connections between the intra- and extraorbital veins may also be located near the lower lateral part of the orbital wall through the lateral collateral vein (Fig. 7). This type of communication occurred in 10 orbits out of 57.

Inferior extraorbital anastomosing vein. Connections from the inferior ophthalmic vein to the pterygoid plexus through the inferior orbital fissure (Fig. 4) existed in 14 orbits out of 57.

Discussion

The technique used in this investigation and previously described in detail (BATHMAN 1974 a) permits a demonstration of the intraorbital veins. These veins though subject to variations have a relatively constant arrangement. In addition to the two well known veins, the superior and inferior ophthalmic veins connecting the anterior part of the orbit with the cavernous sinus, an additional ophthalmic vein has been identified in a relatively large number of cases. This vein designated the medial ophthalmic vein is often fairly wide. It is of importance in the phlebographic diagnosis of intraorbital disorders as its course

- BOUDET CH Premiers résultats de phlébographie orbitaire Thèse Montpellier 1953
- La place du phlébogramme orbitaire dans le diagnostic des tumeurs de l'orbite Arch Ophthal (Paris) 15 (1955) 597
- BRISMAR J (a) Orbital phlebography I Technique To be published in Acta radiol Diagnostica
- (b) Orbital phlebography II Anatomy of superior ophthalmic vein and its tributaries To be published in Acta radiol Diagnostica
 - (c) Orbital phlebography IV The cavernous sinuses and adjacent venous sinuses of the skull base To be published in Acta radiol Diagnostica
- GRWITZSCH M Über die Anastomosen zwischen den Gesicht- und Orbitarvenen Albrecht Graefes Arch Ophthal 29 (1883) 91
- HARAFEE W Orbital venography Radiol Clin N Amer 10 (1972) 63
- HAYE C, CLAY C et VIGNAUD J L'exploration radiologique de l'orbite Arch Ophthal (Paris) 30 (1970) 179
- HENRY J Contribution à l'étude de l'anatomie de l'orbite et de la loge caverneuse par injection d'huile plastique Thèse Paris 1959
- LYONS G The radiological investigation of proptosis Brit J Radiol 43 (1970) 1
- LONGHARDI G and PASERINI A Venography of the orbit technique and anatomy Brit J Radiol 41 (1968) 282
- — Venography of the orbit pathology Brit J Radiol 42 (1969) 184
- OFFRET G et ARON ROSA D Le phlébogramme orbitaire Arch Ophthal (Paris) 25 (1965) 85
- SALAMON G, RAYBAUD C and GRIBOLI F Anatomical study of the blood vessels of the orbit I Proceedings of the second congress of the European Association of Radiology Amsterdam 14-18 June 1971 p 284 Excerpta Medica Amsterdam 1972
- SCHÖRER R und BRÄUER R Orbita Phlebographie Fortschr Röntgenstr 109 (1968) 345
- SEREMBA E Die Orbitarvenen des Menschen und ihr Zusammenhang mit den oberflächlichen Venen des Kopfes Arch Anat Physiol 2 (1869) 154
- VIGNAUD J Phlébographie orbitaire par ponction directe du sinus frontal Le Progrès récents en angiographie cérébrale p 49 Edité par H Fischgold J Metzger et M L Aubert Laboratoires Schering Seppa 1970

situated higher up in the orbit. A single inferior ophthalmic vein may be located as high up in the orbit as the additional vein. Knowledge of this variation is important in order to avoid the diagnosis of an inferiorly situated intraorbital expansive lesion in such cases. It was possible to identify four collateral veins, i.e. veins with an essentially cranio-caudal course interconnecting the superior ophthalmic vein with veins at the orbital floor. It was also possible to systematize variations in their appearance. The medial and lateral collateral veins due to their location on each side of the muscular cone may prove important in the localization of intraorbital expanding lesions. The anterior collateral vein will be affected by disorders in the antero-medial part of the orbit.

The posterior collateral vein was identified in only one fifth of the cases. Its somewhat bizarre appearance especially in the lateral view may tempt an examiner to regard it as a pathologic collateral vein indicating an obstruction of the posterior part of the superior ophthalmic vein. This risk is not insignificant, particularly because in normal cases the diameter of the posterior segment of the superior ophthalmic vein may be greatly reduced.

SUMMARY

The phlebographic anatomy of the orbital veins is described on the basis of material of 7 normal orbits. In addition to the superior and inferior ophthalmic veins, medial ophthalmic vein and four different collateral veins were identified. Diagnostic implications of detailed knowledge of the anatomy of the intraorbital veins are stressed.

ZUSAMMENFASSUNG

Die phlebographische Anatomie der Orbitahenen wird an hand eines Materials von 57 normalen Augenhohlen untersucht. Zusätzlich zu den oberen und unteren Augenhenen werden vier verschiedene Kollaterahenen identifiziert. Die diagnostischen Folgerungen der detaillierten Kenntnis der Anatomie der intraorbitalen Venen werden hervorgehoben.

RÉSUMÉ

Description de l'anatomie phlébographique des veines orbitaires d'après une série de 57 orbites normales. En plus des veines ophtalmiques supérieure et inférieure l'auteur identifie une veine ophtalmique interne et quatre veines collatérales différentes. Il souligne les conséquences diagnostiques d'une connaissance détaillée de l'anatomie des veines intra-orbitaires.

REFERENCES

- ALON, ROSA D., OFFERT, G., RAMKE, A., METZGER, J., AARON, C. et ROSA, A.: La phlébographie orbitaire. *Bull. Soc. Ophtal. F.* (1967) Suppl.
- RAMKE, A. et METZGER, J.: La phlébographie orbitaire. I. L'exploration neuroradiologique en ophtalmologie. p. 136. Edité par F. Guilloit, H. Saraux et R. Sedan. Masson et Cie, Paris, 1968.

the type of the defect and on the existence of associated malformations and their sequelae such as interhemispheric cysts and hydrocephalus (cf. PROBST 1973). As the malformations of the brain mainly involve the structures in the median and paramedian region, or more distinctly speaking the third ventricle, lateral ventricles and medial parts of the hemispheric surfaces, vascular abnormalities of diagnostic significance are likely to be found in vessels closely related to these structures. The relation between the pericallosal artery and the corresponding part of the third ventricle was analyzed in order to assess to what extent the course of the artery is affected by widening of the third ventricle.

Previous investigations. MAURER described some abnormal features in the course of the pericallosal artery, but he did not observe any change of its anterior part. ZELLWEGER had examined 5 patients, and in 3 of them he stated that the pericallosal artery was absent; his figure 4, however, shows clearly this artery and the distinguishing feature in its course, namely the steep rise of its first segment and the absence of the typical anterior part, i.e. the part curving around the callosal knee. This angiographic sign was later described by SHELDON & PRYMAN and subsequently confirmed by most of the later authors. ZELLWEGER, in particular, as well as FISCHER, also stressed the abnormal course and distribution of the callosomarginal artery and its branches. FISCHER discussed the difficulties arising when several irregular arteries running in the interhemispheric fissure are to be classified. SHELDON & PRYMAN, among others, also described changes in the shape and position of the internal cerebral veins, which were found to be elevated. MORRIS mentioned separation of the internal cerebral veins in cases with dilatation of the third ventricle.

Several authors have considered that the axis of the middle cerebral artery group is raised in defects of the corpus callosum (ZELLWEGER, HOLMAN & MAC CARTY, CLAUS & HEIDRICH).

Material. The morphology and encephalographic appearance of defects of the corpus callosum based on a material of 50 cases have been published previously (PROBST 1973). Carotid angiography was performed in 16 of these cases and the vascular abnormalities encountered are correlated to the adjacent anatomic structures in the present report.

Results

The pericallosal artery

The pericallosal artery arises from the anterior cerebral artery as the anterior communicating artery and is normally divided into an inferior, anterior and

ANGIOGRAPHIC FEATURES IN CONGENITAL DEFECTS OF THE CORPUS CALLOSUM

F P PROBST

Carotid angiography is being used with increasing frequency as the first radiologic procedure in mental disturbances or epileptic conditions. The angiographic signs of defects of the corpus callosum are therefore commanding more attention especially since it has become obvious that this condition may be diagnosed by angiography.

Since MAURER (1940) described the first case of agenesis of the corpus callosum examined by carotid angiography, some additional cases have been reported (ZELLWEGER 1952, STEDMAN & PEYMAN 1953, VAN EPPS 1953, FISCHER 1959, HOLMAN & MACCARTY 1959, CLAUS & HEIDRICH 1960, KOSLOVSKI & ALAPIN 1961, KAVICALA 1961, MORRIS 1962, NOBLET et coll 1963, ZINGEBBER et coll 1964, LARSEN 1966, BULL 1967, HANDA et coll 1969, SZEDY et coll 1972). However, the total number of cases up to 1972 did not exceed 20. Additional reporting on cases examined by carotid angiography would seem to be desirable if more detailed knowledge about the vascular abnormalities is to be gained. This would increase the accuracy of the angiographic diagnosis of this malformation and would be especially valuable since the brain abnormalities in agenesis of the corpus callosum vary within rather wide limits depending on

Submitted for publication 7 September 1973



Fig. 2. Complete callosal defect. Carotid angiography venous phase corresponding cephalographic view with composite drawing. The internal cerebral vein is displaced laterally parallel to the inferior sagittal sinus. It appears shortened in the lateral view because its posterior segment (\rightarrow) runs mainly in a medial direction to join its mate and the straight sinus. Vena magna absent. Venous angle located unusually high and posteriorly (\rightarrow).



Fig 1 Complete callosal defect Right carotid angiography and encephalography of 13 months with composite drawing The pericallosal artery follows the dilated third ventricle (d) and decussates towards the spinal side (c) This part of the artery runs in the depth of the cistern of the lateral callosal substitute Its branches (→) curve around an enfolded marginal convolution (←) Enlargement of the posterior fossa due to Dandy-Walker cyst causing elevation of the transverse sinuses (e) The confluens sinuum is located unusually high



Fig 4 Complete callosal defect associated with anteroposterior encephalocystocele, lip palate and left lip and palate. Carotid angiography and encephalography with composite drawings. The pericallosal artery is tilted posteriorly running along the wall of the cystocele and is the epous artery at the same level. A corpus callosum cannot reasonably exist between them. The internal cerebral cisterns are closely adjacent to the midline on the roof of the third ventricle which is not elevated and lacks the usual semiovoid shape.

so far forward and inferiorly that the ascending part did not pass upward anteriorly but posteriorly instead (Fig 4).

The knee The transition between the inferior and superior segments of the pericallosal artery was also abnormal in all cases. The knee had the appearance of a right angled or obtuse angled curve (8 cases) or was more or less acute angled (4 cases) or deformed in other ways (4 cases). It seemed to be situated

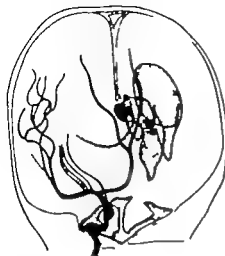


Fig 3 Complete callosal defect associated with vascular expansion process on right side. Composite drawing of angiographic and encephalographic pictures. The common trunk and internal cerebral veins pushed over to the left and the thalamostriate vein is elongated. The arteries to the basal ganglia are stretched and retracted laterally.

superior part (LINDOREN 1954). In cases with agenesis of the corpus callosum the anterior part normally curving around the genu is absent. The inferior part has a more ascending course and forms with the superior part a more or less marked knee.

The inferior (ascending) part. A common stem with bihemispheric division was present in 3 of the 16 cases (Figs 3, 6, 10). In two of these three cases (cf Fig 6) both callosomarginal arteries arose symmetrically from the pericallosal artery at the origin of the anterior communicating artery and in the third asymmetrically, one of the latter originating from the middle part of the common stem (Fig 10). In two cases the common stem ascended fairly steeply and

The stem lay exactly in the midline in two cases and on the left side in the interhemispheric cyst.

The stem lay exactly in the midline in two cases and on the left side in the third. After the bifurcation the branches radiated out symmetrically on the medial surfaces of the hemispheres.

In the other cases double pericallosal arteries were present from their origin. In one the left artery was hypoplastic. The course of these arteries was more or less abnormal. As in the cases with a common stem all arteries except two ascended steeply, taking as a rule the shortest path up to the genu. The left pericallosal artery had an S-shaped curvature in one instance and in another, with a partial callosal defect, the anterior callosal rudiment was distinctly outlined by the artery (Fig 11). In one case the origin of the pericallosal artery was located

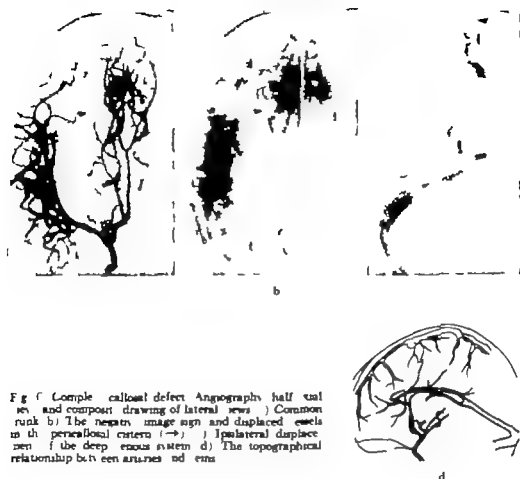


Fig. 6 Complete callosal defect. Angiography half axial view and composite drawing of lateral views. a) Common trunk b) The negative image sign and displaced cisterns in the pericallosal cistern (→) c) Ipsilateral displacement of the deep enous system d) The topographical relationship between arteries and veins

The normal vascular appearance in the films when the pericallosal cistern is projected axially and the small arteries within it thus are superimposed on one another has been named the moustache sign (HUANG 1964) the arteries in the cistern are in such a view located almost horizontally and meet in the midline. When a callosal defect is present they are displaced laterally and directed more or less vertically (Fig. 6).

LILJEQUIST (1967) has mentioned that a negative image of the lateral ventricles is sometimes observed in the late arterial and capillary phases. In two cases (cf. Fig. 6 b) in this material this negative image had the appearance characteristic of callosal defects.

Relation of the pericallosal artery to the third ventricle. By superimposing the angiographic lateral view on the corresponding encephalographic view it was



Fig 5 Complete callosal defect a) Carotid angiography b) Composite drawing of lateral angiographic and roentelencephalic views Deformity of the pericallosal arteries (1) indicates callosal defect Absence of the normal corpus callosum Superior parts (2) the same level as the elevated middle segments of the internal cerebral veins Both are situated lower level than the most dorsally expanding part of the interhemispheric cyst and are displaced towards the ipsilateral side

closer to the base than usual in 3 cases and at a higher level in another 4 cases One case had no distinct knee (Fig 4)

The superior part and its branches This part of the artery occupied a higher level than usual in relation to the base in 3 instances (Figs 1 c 2 c 10 a) and had a lower position in 3 others (Figs 4 a 8 13 b c) In a few cases it looped abruptly posteriorly and inferiorly from a knee situated at a high level (Fig 10) Serpiginous lateral curves of the artery obviously exceeding the normal range were observed in 8 cases (Figs 1 5 6 10—13) These appearances seem to be characteristic (Fig 12)

This deformity arises when the pericallosal artery or its branches penetrates deeply into the fissure between a lateral callosal substitute and the marginal convolution (cf Fig 28 in PROBST 1973) On the way out towards the medial surface of the hemisphere the vessels have to course around the marginal convolution with the result that there arise one or several paramedially situated arterial segments concave upwards in the a.p. views This deformity thus requires for its development the existence of cisterns close to the lateral callosal substitute and infolded cingulate gyri in other words conditions that are specific to the callosal defects it may therefore be considered pathognomonic

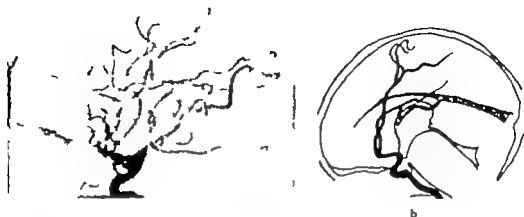


Fig. 9. Complete callosal defect. a) Carotid angiography. b) Corposit drawing of lateral encephalographic and encephalographic views. The pericallosal artery (→) is completely unrelated to the third ventricle. Internal cerebral vein and great vein of Galen flattened as the splenium round which they normally curve is absent.

always situated at a higher than normal level, sometimes at roughly the same level as the horizontal part of the pericallosal artery (Figs 1 c, 4 c, 5 b) and deformed in a more irregular fashion in some cases (Figs 5 b, 10 b). The venous angle occasionally had a relatively high and occipital position.

The subependymal tributaries. The medial veins of the body and trigone were located laterally in all cases, reflecting separation of the lateral ventricles. The thalamostriate vein, caudate veins and the lateral veins of the body and trigone also indicated the shape and lateral extension of the lateral ventricles. Evident septum veins were absent in cases with a complete callosal defect but sometimes occurred when the defect was partial, in other words if an anterior callosal rudiment and a septum pellucidum were present. In one case the paramedian course of the septum vein reflected the separation of the anterior horns due to a cavity of the septum pellucidum (Fig. 11 c).

The great vein of Galen. was absent in one case (Fig. 2 a, b). In most of the other cases the normal wide curve was absent (Figs 7, 8, 9, 13), the vein being sharply angulated with a linked appearance (Fig. 5 b) or running into the straight sinus after coursing more or less parallel to the inferior sagittal sinus (Fig. 11 d). It emerged into the straight sinus more posteriorly in one case, and in 2 cases more anteriorly than normally.



Fig 7 Partial callosal defect Composite drawing of angiographic and encephalographic lateral view. Vertical hatching = entrance to anterior cerebral artery. Black crescentic figure = callosal rudiment. Long anterior callosal rudiment posterior black crescentic area probably small cavity of the septum pellucidum. The dotted area between these represents the callosal rudiment. Location of the callosal rudiment at the base of the posterior cerebral artery which runs abnormally far from the anterior surface of the callosal rudiment. The knee is unrelated to the callosal rudiment. Internal cerebral vein delimits roof of third ventricle situated at normal level. Vena magna has more straight course than normally. Inferior sagittal sinus is located unusually low and forms an acute angle with the internal cerebral vein.



Fig 8 Complete callosal defect Composite drawing of angiographic and encephalographic lateral view. Anterior cerebral artery rises steeply. Its superior part descends to abnormally low level and approaches the level of the roof of the third ventricle and internal cerebral vein. The latter is ipsilaterally displaced and lies at about the same level as the inferior sagittal sinus.

found that the ascending part of the pericallosal artery in 6 cases ran close to the lamina terminalis and to that part of the respective midline cyst adjoining it superiorly (Figs 1 c—e 4 10 f). In 5 of them the first part of the artery had been influenced by the expanding midline cyst and had either been pushed forwards (Fig 4) or had become elongated and sloped forward as in the others (Fig 10 a). In the remaining cases the first part was not related to the lamina terminalis but ran instead at varying distances in front of it (Fig 9 b).

The internal cerebral vein and its tributaries the great vein of Galen

The internal cerebral vein lay close to the midline in 4 cases and about 1 cm to the ipsilateral side in 11 cases (Figs 2 a 6 c 11 c). In one case it was displaced to the contralateral side owing to the presence of an expanding process (Fig 3). The deep cerebral veins in general often had an abnormal appearance being either shorter or flatter than usual (Figs 2 b 6 d 9 b). They were

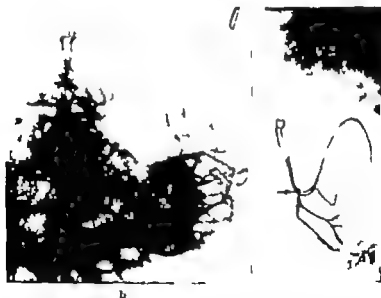


FIG. 11 Partial callosal defect. Carotid angiography. Location of anterior superior part of pericallosal artery (\longleftrightarrow) which with its branches extend abnormally far in the lateral direction within the lateral callosal sulci + cistern (\longleftrightarrow). Drawing of internal cerebral vein () placed laterally (\rightarrow) as is the septal vein which delineates cavum septi.



d



f

Fig 10 Complete callosal defect Carotid angiography lateral half axial supine and p. v. encephalographic p. v. view and composite drawing of lateral x. v. Anterior cerebral arteries unite in the midline to a single trunk closely following the anterior wall of the enlarged third ventricle. At the highest point the two main branches lie over the roof of the interhemispheric cyst and extend laterally into the cleftlike spaces between the cingulate gyri and the lateral callosal substitutes to their lateral termination where the vessels turn upwards. The common trunk as well as the callosomarginal arteries are abnormally wavy. Middle cerebral artery group not changed. Venous angles located higher and more posteriorly than normally (b) and the usual curve of the great vein of Galen is distorted.

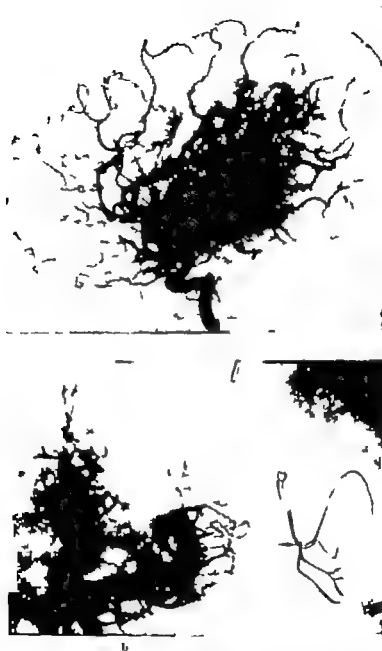


FIG. 11. Partial callosal defect. Carotid angiography. Low position of anterior-posterior part of pericallosal artery (\longleftrightarrow) which with its branches extends abnormally far in the lateral direction within the lateral callosal sulcus to its termination (\longleftrightarrow). Drawing of internal cerebral venous system displaced laterally (\rightarrow) as in the septal vein which delineates cavum septi.



Fig. 12. Schematic drawing showing the basic appearance of the pericallosal artery and its branches in cases with defects of the corpus callosum. They deviate into the cleft between the marginal convolution and the lateral callosal substitute and turn round the marginal convolution ().

The sinous sinuses. The confluens sinuum lay higher than normally in 2 cases (Fig. 1 c). The transverse sinuses also occupied a similar high position from which they descended steeply towards the sigmoid sinuses. The upward displacement of these venous sinuses and of the tentorium attachments was in both cases due to the presence of large cerebrospinal fluid cysts in the posterior fossa. An uncommonly deep falx, which reached far into the interhemispheric fissure, was present in 2 cases. In one of the cases the anterior third of the superior sagittal sinus was absent while the inferior sagittal sinus was unusually wide.

Discussion

This material has revealed that vascular anomalies of various types regularly occur in patients with defects of the corpus callosum, mainly in vessels closely related to the midline structures and the ventricular system. Vessels as distant as the middle cerebral artery and its branches did not deviate from the normal unless other abnormalities were also present (Fig. 1).

The pericallosal artery had an abnormal course in all cases, anomalies being demonstrated either in the inferior or superior part. The former part of the artery usually ascended more abruptly than normally; the anterior part was absent and replaced by a knee which was either rounded or more pointed. In only one of the two cases with an anterior callosal rudiment the pericallosal artery followed and outlined it. The superior part was in half the cases situated

The different angiographic abnormalities seem to vary in diagnostic significance. As with the encephalographic changes, only a few of them possess conclusive evidence as an isolated phenomenon. An integration of the vascular appearance of the arterial-capillary and venous phases into a complete picture is necessary for a conclusive understanding of the condition.

SUMMARY

Carotid angiography was carried out in sixteen patients with encephalographically verified defects of the corpus callosum. Vascular abnormalities in the arterial, transitional and venous phases in various combinations and of largely characteristic type were encountered in all cases. They are discussed with regard to their value as evidence of callosal defects.

ZUSAMMENFASSUNG

Die Karotis-Angiographie wurde bei sechzehn Patienten mit encephalographisch nachgewiesenen Defekten des Corpus callosum ausgeführt. Gefässeränderungen während der arteriellen, der Übergangs- und der venösen Phase in verschiedenen Kombinationen und von sehr charakteristischem Bild wurden in allen Fällen angetroffen. Diese werden hinsichtlich ihres Wertes als Beweis eines Callosum-Defektes diskutiert.

RÉSUMÉ

Une angiographie carotidienne a été faite chez seize malades atteints de malformations du corps calleux, confirmées par encephalographie. Dans tous les cas on a constaté des anomalies vasculaires aux phases artérielle, intermédiaire et veineuse en combinaisons variées et de type très caractéristique. Les auteurs étudient leur valeur comme signes de malformations du corps calleux.

REFERENCES

- BELL, J. The corpus callosum. *Clin. Radiol.* 18 (1967) 2.
 CLAY, R. und HEIDRICH, R. Das Angiogramm beim Balkenmangel. *Fortschr. Röntgenstr.* 92 (1960) 147.
 FISCHER, P. A. Das angiographische Bild des Balkenmangels. *Dtsch. Z. Nervenheilk.* 180 (1959) 40.
 GRATER, W. und HERRMANN, E. Missbildungen der Medianstrukturen des Gehirns. *Der Radiologe* 11 (1966) 453.
 HAND, J., TERAKURA, T., IMAI, T. and HANDA, H. Agenesis of the corpus callosum associated with multiple developmental anomalies of the cerebral arteries. *Radiology* 91 (1967) 1331.
 HOLMAN, C. B. and MACCARTY, C. S. Cerebral angiography in agenesis of the corpus callosum. *Radiology* 1957 317.
 HILARIO, T. II. and WOLF, H. S. Angiographic features of the pericallosal cistern. *Radiology* 87 (1964) 14.

of the corpus callosum. Such lateral curves would not be possible without corresponding clefts in the medial wall of the hemispheres—the cisterns of the lateral callosal substitutes. This feature, as well as the course of the arteries curving around the marginal convolution, produces the pathognomonic appearance that may appropriately be called the callosal defect deformity of the pericallosal artery. The laterally displaced branches in the pericallosal cistern and the negative image of the ventricular system are other characteristic signs.

Abnormalities of the deep venous system were always present and of great diversity, often characteristic. A marked ipsilateral location of the internal cerebral vein occurred in just over half the cases, depending on the degree of dilatation of the third ventricle: it can probably be taken as a useful indicator suggesting the presence of a corpus callosum defect if due consideration be paid to other relevant abnormalities. Displacement due to pressure from the other side or traction due to an ipsilateral reduction of hemisphere volume need to be excluded. An abnormally high position of the deep cerebral veins, and an abnormal relation of these vessels to the inferior sagittal sinus and the pericallosal artery, may also be encountered (LARSEN).

Abnormal shortness of the internal cerebral veins, which appears to be a reflection of wide foramina of Monro and absence of the normal curve of the vena magna, were often demonstrated.

The subependymal tributaries of the internal cerebral vein indicate the boundaries of the lateral ventricles. Each vein must be identified in both a p and lateral views. The location in the half axial a p projection correlated with that in the lateral view gives the best assessment of the course and sites of origin of the afferent veins. An ipsilateral displaced internal cerebral vein, similar displacement of the thalamostriate vein with a narrow or at least not widened arch combined with long trigone veins widely distributed, may be regarded as the typical appearance in callosal defects. These features in addition to the separation reflect discrepancy in the width between the anterior and posterior parts of the lateral ventricles (cf. PROBST 1973).

The anomalies of the venous sinuses in the posterior fossa seem to have been the result of abnormal pressure conditions in that region which prevented the tentorial attachment from descending. They were thus not related to the absence of the corpus callosum but constituted a developmental disturbance traceable to an associated malformation in the posterior fossa. The occurrence of common pncallosal trunks (in 3 out of 16 cases) was probably not incidental: it might be a vascular dysplasia with a direct relationship with the same defective developmental mechanism as that leading to the callosal defect. However, this anomaly not infrequently occurs also in normal brains (in about 4 per cent of cases: LE MAY & GOODING 1966).

THE COCHLEAR AQUEDUCT

ANDERS HENNINGSSON and PER GUNNAR IJENDÖREN

Histologic examinations of the cochlear aqueduct were performed some decades ago by HARLTFORS (1924) MEURMAN (1930) and KARBOWSKI (1930) among others, and more recently by WALTNER (1947-1948) ANSON et coll (1964-1965) RITTER & LAWRENCE (1965) HENNEFORD & LINDSAY (1968) PALVA & DAMMERT (1969) and PALVA (1970). Opinions differ as to whether or not the aqueduct is open and allows free passage of cerebrospinal fluid from the subarachnoid space to the scala tympani. PALVA & DAMMERT however concluded that fluid exchange through the cochlear aqueduct was fully feasible but stated that its course and structure are not sufficiently known, for instance in cases of Meniere's disease. According to DORF et coll (1973) an unusually wide aqueduct may be a possible cause of fistulas following stapedectomies.

The present investigation was therefore undertaken to determine whether the cochlear aqueduct can be demonstrated at roentgen examinations of temporal bone specimens as well as of living subjects. To our knowledge the roentgenologic appearance of the whole cochlear aqueduct has not been described previously.

Anatomy. The cochlear aqueduct contains the cochlear canaliculus which passes from the subarachnoid space in the posterior cranial fossa to the per-

Submitted for publication 17 December 1973.

- KORLOW N P and ALAPIN B On cerebral angiography in agenesis of the corpus callosum
Quoted by NOBLET et coll
- KVICALA V Quoted by NOBLET et coll
- LARSEN J L Angiographic findings in agenesis of the corpus callosum Amer J Roentgenol
98 (1966) 579
- LE MAY M and GOODENO C A The clinical significance of the artery anterior cerebral
artery (ACA) Amer J Roentgenol 98 (1966) 602
- LENGUET B Capillary phase in cerebral angiography Acta radiol 6 (1967) 113
- LEUDGMAN E Röntgenologie I Handbuch der Neurochirurgie Bd 2 Herausgegeben von H
Olivcrona und W Tonnus Springer Verlag Berlin 1954
- MORAN L Agenesis of corpus callosum New angiographic sign Brit J Radiol 35 (1962)
423
- MALIER H Zur encephalographischen Diagnose des Balkenmangels Der Nervenztr 13
(1940) 454
- NOBLET M P SHAPIRO J H and FRYE D M The cerebral angiogram in agenesis of the
corpus callosum Amer J Roentgenol 90 (1963) 522
- PROBST F III Congenital defects of the corpus callosum Morphology and encephalographic
appearances Acta radiol (1973) Suppl No 331
- SCHILDEN PH and PEYMAN A The radiological appearances of agenesis of the corpus callosum
J Neurol Neurosurg Psychiat 16 (1953) 117
- SEIDUT D LIEBERMAN R and NICKEL B Common trunk of the anterior cerebral arteries
Neuroradiology 4 (1972) 51
- ZELLWEGER H Agenesis corporis callosi Helv paediat Acta 7 (1952) 136
- ZWISLOCKI L SCHLICHTER M GONATAS N LEVY A and WISOFF H Agenesis of the corpus
callosum associated with inter hemispheric arachnoid cyst Brit J Radiol 37 (1964) 905
- VAN EPPS E F Agenesis of the corpus callosum with concomitant malformations including
atresia of the foramina of Luschka and Magendie Amer J Roentgenol 70 (1953) 47

Table

Number of cases with the cochlear aqueduct visible in at least one of the

Diagnosis	Age (in years)			Total
	< 10	10-20	> 20	
Normal	3/3	1/2	3/5	7/10
Meningitis disease			7/9	7/9
Fracture			0/2	0/2
Otitis chronica		1/2	4/16	5/18
Otosclerosis			1/1	1/1
Carcinoma			1/1	1/1
Total	3/3	2/4	16/34	21/41

examined histologically by PALVA & DAMMERT the smallest width was 80 to 150 μ that is about 0.1 to 0.15 mm and the width gradually increased in both directions, to about 0.2 to 0.5 mm at the internal orifice and about 0.5 to 2.4 mm at the external aperture. At histology PALVA (1970) found that in six infant temporal bones the width of the cochlear aqueduct was somewhat greater than in adults. The length of the aqueduct measured from the bottom of the external aperture to the internal orifice at the scala tympani averaged 6 mm in adults (PALVA & DAMMERT) and 3.5 mm in infants (PALVA).

Material and Method To determine the best projection for demonstrating the cochlear aqueduct at roentgen examination a titanium thread with a diameter of 0.1 mm was introduced into the aqueduct in eight adult temporal bones. None of the subjects from whom these bones were taken had had any history of ear disease. The specimens were examined in true a.p. projection, in a p. projection with medial and lateral rotations in 5 steps and in axial projection with 5 steps of medial and lateral inclination.

The aqueduct was uncovered by means of a dental drill (Fig. 2) to confirm that the thread lay in the correct position.

Eight specimens without a thread and 41 patients were also examined in the a.p. projection found optimal for demonstration of the aqueduct in the specimens with the titanium thread. The ages and diagnoses of the patients are given in the Table.

A Polytome was used with 0.5 mm cuts and hypocycloidal movement; the focal spot was 0.3 mm. The new Kodak X-omatic Fine film screen system was used for the specimens and the Kodak X-omatic Regular film screen system for

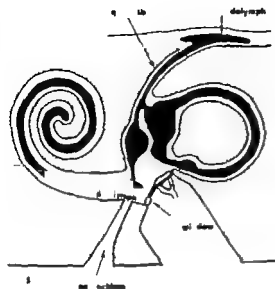


Fig 1 Perilymphatic and endolymphatic spaces

lymphatic space in the basal coil of the cochlea (Fig 1). This space surrounds the membrane wall in the cochlear duct, the utricle, the saccule and the semicircular canals. The chemical compositions of perilymph and endolymph are different; immunologically the perilymph seems to be similar to CSF (PALVA & DAMMERT 1969).

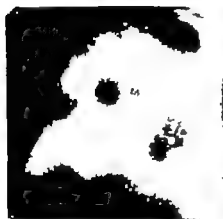
The external aperture of the cochlear aqueduct is funnel shaped; the aqueduct gradually narrows to the smallest width 0.5 to 1.5 mm from the internal orifice to the scala tympani, after which it again widens. In 20 adult bone specimens



Fig. Photograph of specimen with the titanium thread in the exposed aqueduct



Fig 5 Tomogram in the 5° p projection of an adult patient with Meniere disease. The entire length of the cochlear aqueduct α (\rightarrow) is visible.



b

Fig 6 Tomograms of the same specimen as in Fig 4 a) Film screen combination Kodak RPL (film—Siemens Universal screens) b) Kodak G (film—Kodak Nomatic Regular screens). The noise is most evident ()

Results

The whole thread length in the aqueduct from the external aperture to the internal orifice was demonstrated in a p projection with the temporal bone rotated 5° laterally (Fig 3 a) i.e. the head should be turned 5° from the straight a p position towards the transorbital Guillen projection. The axial projection with 20° medial inclination (Fig 3 b) also demonstrated the whole thread.

The aqueduct of the specimens without the thread (Fig 4) could be observed in its entire length in 6 of the 8 bones in the a p view with 5° lateral rotation and in the axial view with 20° medial inclination. The short aqueducts were nearly straight in their downward course (Fig 4 a) while the longer ones were slightly curved (Fig 4 b).



Fig 3 Tomogram of specimen in a) 5 mm and b) 20 mm axial projections. A tantalum thread (→) has been placed in the cochlear aqueduct. 1 = superior semicircular canal, 2 = internal acoustic meatus, 3 = horizontal semicircular canal, 4 = cochlea, 5 = middle ear.

the patient. The exposure data were 55 kV, 6.4 s, 10 mA for the former and 60 kV, 12.8 s, 32 mA for the latter. General (G) Kodak film was used in both systems.

The resolution capacity and the noise level of the Kodak X-omatic Regular system was compared with those of Siemens Universal screens combined with Kodak RPL film by means of tomograms of the same specimen exposed with the same data.



b

Fig 4 Tomogram of specimens in a) 5 mm, b) 10 mm and c) 20 mm axial projection. The longer cochlear aqueduct in (b) is more curved and has a downward course than the shorter one in (c). Arrow indicates the aqueduct.



Fig. 5 Tomogram in the 5° p projection of an adult patient with Meniere disease. The entire length of the cochlear aqueduct (→) is visible.



b

Fig. 6 Tomograms of the same specimen as in Fig. 4. a) Film-screen combination Kodak RPL film—Siemens Universal screens. b) Kodak G film—Kodak X-omatik Regular screens. The noise is most evident in (a).

Results

The whole thread length in the aqueduct from the external aperture to the internal orifice was demonstrated in a p projection with the temporal bone rotated 5° laterally (Fig. 3 a), i.e. the head should be turned 5° from the straight a p position towards the transorbital Guillen projection. The axial projection with 20° medial inclination (Fig. 3 b) also demonstrated the whole thread.

The aqueduct of the specimens without the thread (Fig. 4) could be observed in its entire length in 6 of the 8 bones in the a p view with 5° lateral rotation and in the axial view with 20° medial inclination. The short aqueducts were nearly straight in their downward course (Fig. 4 a) while the longer ones were slightly curved (Fig. 4 b).

The bony structure was more clearly visible and the noise level lower in tomograms with the Kodak N-omatic than with the conventional film screen system (Fig 6)

Discussion

This investigation has revealed that for examination of the cochlear aqueduct a p projection with 5° rotation of the head towards the tran orbital (Guillen) projection or axial projection with 20° medial inclination should be used. These projections seem to be more appropriate than the S7° a p projection described by DOWDY *et al* (1973). The aqueduct was demonstrated in most specimens which supports the view of PALVA & DAVVET that at least its bony part is open.

The aqueduct could be demonstrated in about half of the patients (Table). It was most difficult to outline in patients with chronic otitis probably because of the sclerotic bone in these cases. It could be observed in most of the adult normal subjects as well as in all children. In this small material there was no difference between normal subjects and patients with Meniere's disease.

The small diameter of the cochlear aqueduct places high demands upon the tomographic equipment and the film screen system. The new Kodak N-omatic system has lower unsharpness and a lower noise level (REICHMANN & HELANDER 1974) than the conventional systems (Fig 6) which is of importance for the demonstration of small structures with low contrast.

Conclusion

The entire length of the cochlear aqueduct may be outlined in tomograms with an inclination of the head 5° laterally and 20° medially in a p and axial projections respectively. The shape and course of the aqueduct varied. In the present clinical material it could be observed in about half of the 41 cases.

The new Kodak N-omatic film screen system with its low noise level and low geometric unsharpness seems to be an improvement in the rendering of details in ear tomograms.

SUMMARY

The cochlear aqueduct could be demonstrated in tomography of temporal bone specimens and in about half of the cases in clinical material in p projection with 5° lateral rotation and in axial projection with 20° medial inclination. No difference between normal subjects and patients with Meniere's disease was encountered.

introduced by CAMPBELL *et coll.* (1964) for lumbar myelography it rapidly gained popularity owing to its excellent contrast producing properties, rapid resorption from the subarachnoid space and low toxicity making spinal anaesthesia unnecessary. Notwithstanding, the present authors (Autio *et coll.* 1972) reported a high incidence of adhesive arachnoiditis after lumbar myelography with 7 ml meglumine iohalamate in patients subjected to repeat myelography without intervening operative procedures. The main radiographic features of adhesive arachnoiditis were obliterated root sleeves, disappearance of the striated appearances of the intrathecal nerve roots and constriction of the dural sac; the adhesions were most marked in the lowermost sacral root sleeves. The observations were soon confirmed by RADBERG & WENNBERG (1973) and HALABURT & LESTER (1973).

The question then arose as to whether the intrathecal reactions observed could be attributed partly to the physico-chemical properties of the agents. Preliminary experiments revealed that the pH changes in the cerebrospinal fluid (CSF) after instillation of contrast media were small, whereas the concentrated contrast solutions, hyperosmolar in comparison with the CSF, induced a dose dependent increase of osmolality in samples taken after their addition *in vitro*. The high osmotic gradient between the CSF and the neural elements, regarded as a factor potentially contributing to the adhesive arachnoiditis after lumbar myelography, called for further clinical analysis.

Alterations in the osmolality of the CSF in this clinical series during and after routine lumbar myelography with different contrast media, were compared with the data on the incidence and site of lesions radiographically observable. The results indicated a close relationship between osmolar disturbances in the CSF and the occurrence of adhesive arachnoiditis.

Material and methods The series comprised 41 patients subjected to lumbar myelography on account of sciatic pain. In 10 patients, the osmolality of the CSF was measured in connection with the first myelography according to the schedule described; in another 31 patients the position and severity of adhesive arachnoiditis demonstrable were determined from films obtained from the first and a repeat myelography without intervening operative procedures.

The first myelography had been made with 10 ml Kontrast U (odium methiodal) in 14 patients, with 7 ml Conray Meglumine 282 (meglumine iohalamate) in 13 patients and with 5 ml Dimer X (meglumine iocarmate) in 4 patients.

Lumbar myelography was carried out with the patient lying on the left side on a roentgen couch tilted head up from about 10 to 40 degrees. Spinal anaesthesia with 1.5 ml Xylocain tung preceded injection of the Kontrast U.

HYPEROSMOLALITY OF THE CEREBROSPINAL FLUID AS A CAUSE OF ADHESIVE ARACHNOIDITIS IN LUMBAR MYELOGRAPHY

P. SLATIS, E. AUTIO, J. SUOLANEN and S. NORRBACK

Contrast media injected into the lumbar subarachnoid space affect the leptomeninges and cause either histologically visible reactions or clinically demonstrable irritation of the nerve roots. HARVEY & FRIEBERGER (1965) reviewed the adverse local effects of water soluble sodium methiodal (Abrodil, Contrux, Kontrast U) and demonstrated dose dependent toxic effects on leptomeningeal structures and nerves in dogs. PRÄSTHOLM & ØLOGAARD (1972) presented similar evidence of leptomeningeal reactions after meglumine iothalamate (Conray) reporting cell infiltration into the meninges after subarachnoid instillation of the medium in rabbits.

Clinically the water soluble contrast media hitherto used for lumbar myelography have caused notable irritation of the neural elements and pinal anaesthesia before their use has become mandatory. Reports of severe neurologic complications have appeared (LINDBLOM 1947; PANTER 1953; MUYRO 1956; SÖDERBERG *et coll.* 1958; BJÖRSTRUP 1972). Hence when meglumine iothalamate was in

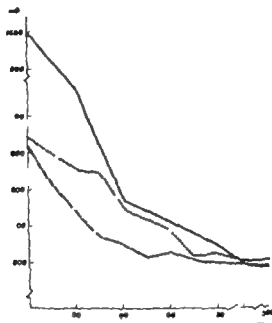


Fig 1 Osmolality of the cerebrospinal fluid after injection of various contrast media. — Kontrast U (10 ml) - - - Conray Meglumine (1 ml) . . . Dimer X (7 ml)



Fig 2 Osmolality of the cerebrospinal fluid at different levels after injection of Dimer X. — L5/S1 (4.5 ml) - - - L5/S1 (4.0 ml) . . . L4/L5 (7.0 ml) — — L5/L4 (5.0 ml)

Osmolality of the CSF at different levels after injection of various contrast media Three lumbar needles were introduced through the three lowermost lumbar interarcuate ligaments into the subarachnoid space. Samples were taken from the L3/L4, the L4/L5 and the L5/S1 segments after injection of contrast media.

Table 1 indicates that the highest values for osmolality were recorded in the lowermost segment L5/S1 regardless of the contrast medium. Hyperosmolality was most notable after the injection of Kontrast U and least after the adminis-

Table 1

Osmolality (mOsm/kg H₂O) of the cerebrospinal fluid taken from the three lowermost lumbar segments 1 to 2 min after subarachnoid injection of various contrast media

Contrast medium and amount injected	Osmolality of the CSF after injection of the medium measured at the level of		
	L3/L4	L4/L5	L5/S1
Contrast U (10 ml)	1 190	1 400	1 500
Conray (ml)	520	550	550
Conray (7 ml)	620	620	640
Dimer \ (5 ml)	450	480	540
Dimer \ (5 ml)	450	460	4 0
Dimer \ (7 ml)	520	590	6

it was not performed in patients subjected to lumbar myelography with Conray Meglumine 282 or Dimer \. Initially 7 ml Conray was thoroughly mixed with 3 ml of CSF. Appropriate films were obtained in lateral prone and both oblique projections with a vertical beam in the TV image intensifier. The contrast medium was not aspirated. The patient was instructed to remain in a semirecumbent position for 6 hours after completion of the examination.

Osmolality was obtained with a Fiske osmometer by measuring the freezing point depression in samples of CSF. The normal osmolality of the CSF as of the intra- and extracellular fluids, is 290 ± 10 mOsm/kg H₂O.

Samples of CSF were obtained during and after myelography either through single lumbar needles or three simultaneously inserted lumbar needles. Care was taken to achieve their proper positioning. After injection of the contrast medium 1 to 2 minutes was allowed for equilibration before the first sample was taken. Further samples were obtained if necessary at 15 minute intervals. Analysis of the films from the primary and the repeat myelography revealed signs of adhesive arachnoiditis at the second examination. The changes were classified according to the position and severity into four stages: stage 0 indicating a normal myelography and stage III gross adhesions and constriction of the leptomeningeal spaces.

Results

The osmolality of the CSF rose instantly to high values after injection of the contrast media. The changes seemed to be dose dependent and related to the medium.



Fig. 3 a) First myelography with 10 ml Kontrast U. Good filling of the lumbar and sacral root sleeves. b) At repeat examination with Conray disappearance of the striated structure in the lower part of the dural sac which is moderately constricted. The left sacral root pouches remain unfilled and the left L5 root sleeve is blunted. Stage II alterations.

Fig. 4 a) First myelography with 7 ml Conray oblique. Good filling of the root sleeves with small cystic dilatation of one sacral root pouch. b) At repeat examination the sacral and L5 root sleeves remain unfilled. The dural sac is moderately constricted. Stage II iterations.

Fig. 5 Myelographies with ml Dimer N. a) First myelography. Protrusion of the intervertebral disc L5/S1 on the right side. b) Second myelography without intervention. Good filling of all unaffected root sleeves. The striated structure of the dural sac is retained. No adhesions. Stage 0.

Conray in a moderate dose (4 ml) raised the osmolality of the CSF to 730 mOsm/kg H₂O. In another patient injection of 5 ml Conray increased the osmolality to 550 mOsm/kg H₂O and a further addition of 2 ml Conray raised this to 610 mOsm/kg H₂O.

Dimer N (4 ml) induced an osmolality of 450 mOsm/kg H₂O. In another patient 4.5 ml caused a corresponding increase to 560 mOsm/kg H₂O. In 3 patients injection of 5 ml Dimer N raised the osmolality values of the CSF to 475, 540 and 560 mOsm/kg H₂O respectively. In another patient 5 ml Dimer N increased the osmolality to 470 mOsm/kg H₂O and the addition of 2 ml medium raised the osmolality to 625 mOsm/kg H₂O.

These results suggested that the addition of 2 ml of contrast medium to raise it from 5 to 7 ml increased the osmolality of the CSF by 90 to 135 mOsm/kg H₂O.

tration of 5 ml Dimer X. No value obtained was within the normal range thus the area defined in the films by the medium contained a cerebrospinal fluid with hyperosmolar properties the values being most aberrant in the lowermost segments.

Spinal anaesthesia with 1.5 ml lidocain induced displacement in CSF osmolality from the normal value of 290 mOsm/kg H₂O to 530 mOsm/kg H₂O at the level of L5/S1. The extremely high value after the subsequent injection of Kontrast U (1500 mOsm/kg H₂O) obviously reflected an additive effect of the two media instilled into the subarachnoid space.

Osmolality of the CSF 6 hours after injection of various contrast media. The duration of the hyperosmolar state in the lumbar area after myelography was determined as follows: the lumbar needle was introduced through the L5/S1 interarcuate ligament into the subarachnoid space and after completion of the examination samples were taken at 15 minute intervals for two hours and subsequently by repeated spinal punctures at two-hour intervals until six hours after the examination. The osmolality curves have been compiled in Fig. 1. After injection of Kontrast U the initial value of 1500 mOsm/kg H₂O fell rapidly to 480 mOsm/kg H₂O within one hour but the osmolality values were not normal until four hours after injection of the contrast medium; this may be attributed partly to the slow resorption of lidocain. Contray (7 ml) induced a CSF osmolality of 640 mOsm/kg H₂O and the values for the successive samples reached almost normal levels within two hours. Dimer X (7 ml) induced slightly lower initial osmolality values, and the decline of the curve was even more rapid (Fig. 1). Six hours after injection of the media all values obtained were within the normal range.

Osmolality of the CSF at different levels after injection of Dimer X. Lumbar needles were introduced through the three lowermost interarcuate ligaments into the subarachnoid space and serial samples taken during two hours (Fig. 2). The declining curves of the osmolality values had different inclinations at the three lumbar levels. Osmolality remained high at the L5/S1 level but rapidly returned to values within the normal range in the higher segments.

Osmolality after injection of various amounts of Kontrast and Dimer X. The influence of increasing amounts of contrast medium on the osmolality value was determined. The lumbar needle was introduced through the L5/S1 interarcuate ligament into the subarachnoid space and CSF samples were taken after instillation of different amounts of contrast media.

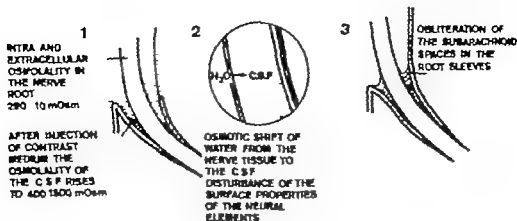


FIG. 6. Changes in the osmotic equilibrium of the cerebrospinal fluid after injection of contrast media and assumed sequence of events resulting in adhesive arachnoiditis.

brospinal fluid. Of the different media tested sodium methiodal caused an increase of the CSF osmolality from the normal 290 mOsm/kg H₂O to 1500 mOsm/kg H₂O far surpassing the values obtained with other media. It should be noted that this is the only contrast medium of the present series which requires spinal anaesthesia before its injection. The other media (Conray and Dimer X) have a less profound influence on the osmotic equilibrium of the CSF and may be used without anaesthesia, but signs of irritation of the nerve roots such as tic movements and muscle spasm have been reported (AHLGREN 1969; EDGREN & TALLROTH 1970; IIRIÄMÄ *et al.* 1970; PRÄSTHOLM & LÖFSTER 1970; GONSETTE 1971; ALTO *et al.* 1972; HAMMER & SCHREIBER 1972; JEFFERY & SEPPÄNEN 1972).

The osmotic values measured at different levels revealed the highest values in the lowermost part of the cul de sac; they remained high long after they had reached normal levels in the upper segments. High osmolality values were still recorded one hour after injection of the contrast medium; this corresponds to the period when media may still be observed in the films.

The hyperosmotic state occurring in the lumbar subarachnoid space after introduction of media is dependent both on the medium and on the amount injected. The osmotic pressure induced by any given substance dissolved in water is based upon the number of particles of solute in solution and not on characteristics of weight, electrical charge, or shape of the dissolved particle (BOND & BAKER 1971). Much can be done to reduce the osmotic properties of contrast media available by reducing the number of particles producing a given amount of contrast; the physicochemical properties of Dimer X are more favourable in this respect than the other media used in this series.

Tabl 2

Frequency and severity of adhesive arachnoiditis after various water soluble contrast media

Contrast medium		N of patients	Severity of adhesive arachnoiditis			
			0	I	II	III
Kontrast U	(10 ml)	14	5	4	4	1
Conray						
Meglumine 28%	(7 ml)	13	2	7		
Dimer X	(5 ml)	4	4			

Comparison of the films from the two successive myelographies revealed characteristic alterations: the first and constant sign of adhesive arachnoiditis was obliteration of the sacral root sleeves and disappearance of the striated structure of the lowermost dural sac. If the reaction was more profound similar changes could be observed in the lumbar root sleeves advancing cephalad from L5. The dural sac in severe cases appeared constricted. The following radiologic classification was made on this basis (Figs 3-4-5):

Stage 0	No signs of adhesive arachnoiditis in the root sleeves or dural sac
Stage I	Obliteration of the sacral root pouches and disappearance of the striated structure normally visible in the dural sac
Stage II	The sacral root sleeves remain unfilled; the fifth lumbar root sleeves are blunted. The dural sac is moderately constricted at the level of the fifth lumbar vertebra
Stage III	All sacral root pouches and the fifth lumbar root sleeve remain unfilled; the fourth lumbar sleeve is blunted. The dural sac is severely constricted at the level of the fifth lumbar vertebra

The series was subdivided according to this classification and the contrast medium (Table 2). It emerged that 10 ml Kontrast U and 7 ml Conray Meglumine induced adhesive arachnoiditis of approximately equal severity. It should be noted that of the patients examined with Kontrast U and Conray Meglumine 5/14 and 2/13 respectively had no untoward reactions at repeat myelographies. In the small group examined with Dimer X no adhesion could be demonstrated at repeat myelography and this medium thus appeared to cause only a low incidence of arachnoiditis.

Discussion

This investigation indicates that the commonly used contrast media when injected into the subarachnoid space induce hyperosmolar changes in the cere

been erroneously assumed to be postoperative adhesions in retrospect it is evident that most of these patients had adhesive arachnoiditis. This has also been pointed out by HALABURT & LESTER (1973). Myelography may still be used in clinical practice: the indications should be strictly delineated, a small amount of contrast medium should be used, and the manufacturers should pay due attention to the osmolar properties of their products.

SUMMARY

Adhesive arachnoiditis was frequently observed after lumbar myelography with 10 ml Kontrast U and 7 ml Conray Meglumine 282 but not with 5 ml Dimer X. These water soluble contrast media induced hyperosmolality of the cerebrospinal fluid related both to their type and the amount injected: the degree of hyperosmolality was correlated to the severity of the subsequent adhesive arachnoiditis. Dimer X produced the lowest changes.

ZUSAMMENFASSUNG

Eine Adhäsions-Arachnoiditis wird häufig nach lumbaler Myelographie mit 10 ml Kontrast U und 7 ml Conray Meglumine 282 jedoch nicht mit 5 ml Dimer X beobachtet. Diese wasserlöslichen Kontrastmittel verursachen eine Hyperosmolarität der Cerebrospinalflüssigkeit, die sowohl von deren Typ als auch zur injizierten Menge relativiert war. Der Grad der Hyperosmolarität ist zum Ausmass der nachfolgenden adhärenten Arachnoiditis korreliert. Dimer X bewirkt die geringsten Veränderungen zur Folge.

RÉSUMÉ

Les auteurs ont observé fréquemment une arachnoïdite adhésive après radiculographie lombosacrée faite avec 10 ml de Kontrast U et 7 ml de Conray Meglumine 282 mais pas avec 5 ml de Dimer X. Ces moyens de contraste hydrosolubles provoquent une hyperosmolarité du liquide céphalo-rachidien en rapport à la fois avec leur type et avec la quantité injectée. Le degré d'hyperosmolarité est en rapport avec la gravité de l'arachnoïdite adhésive ultérieure. C'est le Dimer X qui donne les modifications les plus faibles.

REFERENCES

- ALLGREN, P. Lumbar Myelographie mit Conray Meglumine 282. *Fortschr. Röntgenstr.* 111 (1969) 270.
 AUTIO, E., SUOLANEN, J., NORRBACK, S. and SLATIS, P. Adhesive arachnoiditis after lumbar myelography with meglumine isothalamate (Conray). *Acta radiol. Diagnosis* 12 (1972) 17.
 BRODIE, P. P. A case of chronic adhesive arachnoiditis after lumbar myelography with methiodal sodium. *Neuroradiology* 3 (1972) 157.
 BOYD, D. R. and BAKER, R. J. Osmometry: a new bedside laboratory aid for the management of surgical patients. *Surg. Clin. N. Amer.* 51 (1971) 241.

Dilution experiments in our laboratories have revealed that dilution of Dimer X with distilled water in a ratio of 1 : 1 gives a solution with an osmolality of 480 mOsm/kg H₂O whereas mixing the contrast medium with CSF increases the osmolality of the solution to 620 mOsm/kg H₂O. This indicates that in clinical work the medium should be diluted with distilled water not with CSF before it is injected into the subarachnoid space.

It was also demonstrated that the amount of medium should be kept at a minimum. At low doses of Conray and Dimer X, the osmolality of the CSF remains reasonably low (Fig. 2) and this is correlated with a lower frequency of adhesive arachnoiditis (Table 2). If the osmolality of the CSF can be kept below 500 mOsm/kg H₂O during lumbar myelography, the occurrence of adhesive reactions is in the light of the present series unlikely. The importance of low doses of contrast media was recently stressed by HALABURT & LESTER (1973) who noted a decrease in the incidence of adhesive arachnoiditis from 80 to 10 per cent when the dose of Conray was lowered from 7.5 to 5 ml.

A possible explanation of the chain of events that follow instillation of media and ultimately result in adhesive arachnoiditis is given in Fig. 6. Injection of a hyperosmolar contrast solution into the subarachnoid space suddenly increases the osmolality of the cerebrospinal fluid. The osmotic gradient between the fluid on the one hand and the cells of the surrounding tissue on the other increases the displacement of water through the cell membrane to the subarachnoid space. This gradient is highest in the lowermost part of the dural sac and primarily affects the sacral roots where surface injury to the neural elements is most probable. The injury to the delicate surface structures of the neural roots and root pouches may be accomplished either by mechanical disintegration of the surface cells or by cell death due to extensive dehydration or both. The subarachnoid tissue then adheres to the pia around the root sleeves and obliterates these. The tissue lesion is partly covered with fibrous tissue which causes gradual constriction of the dural sac. Such leptomeningeal fibrosis has been described in dogs by HARVEY & FREIBERGER (1965) and in rabbits by ZETTLER (1969) and FRANKSTHOLM & OLGAARD (1972).

Control examinations of the present material have been made since these radiologic features became evident. So far, however, few if any signs or symptoms of arachnoiditis have been detected clinically. The difficulties in this respect should be emphasized since many of the patients have low back pain of long standing with or without previous neurologic signs and an accurate differential diagnosis is often impossible. The main drawback of the radiologic signs of adhesive arachnoiditis is the blurring effect of successive myelographies which renders their interpretation difficult. Many of the myelographic changes observed during previous years in patients subjected to operation have obviously

DIFFERENTIAL DIAGNOSIS OF SPACE OCCUPYING LESIONS IN THE KIDNEYS WITH THE SCINTILLATION CAMERA

S. NORDLANDER and P. J. ÅSAPD

Diagnosis of patients with possible renal tumours is often trying for the patient. This holds especially true for the old patient with a renal mass lesion accidentally detected for instance at urography for a prostatic lesion. A method less trying for the patient than angiography but allowing differentiation of malignant tumours from benign cysts with the same degree of accuracy has been desired since a long time. The results with scintigraphy of the kidneys using the scintillation camera is now reported. Similar methods have been described previously (BLACK *et al* 1966, ROSENTHALL 1967).

Material

Renal mass lesions detected at urography were examined by the scintillation camera, nephroangiography and percutaneous renal puncture. The results were compared and correlated to microscopy of the operation specimen. The material consisted of 38 patients of these only 3 were women. The mean age was 64

- CAMPBELL R L, CAMPBELL J A, HEIMBUERGER R F, KALSBECK J F and MEALEY J
Ventriculography and myelography with absorbable radiopaque medium. *Radiology* 82
(1964) 286
- ENCKEN W and TALLROT H. Lumbal myelografi med jodtalaminmeglumum. (In Swedish)
Nord Med III (1970) 564
- GOMETTE H. An experimental and clinical assessment of water soluble contrast medium in
neuroradiology. A new medium Dimer N. *Clin Radiol* 22 (1971) 141
- HALLARIET H and LESTER J. Leptomeningeal changes following lumbar myelography with
water soluble contrast media (meglumine isothalamat and methiodal sodium). *Neuro-
radiology* 5 (1973) 70
- HANSEN B and SCHJØRRER H. Choice of contrast medium in lumbosacral myelography.
Neuroradiology 1 (1972) 114
- HARVEY J H and FREIBERGER R H. Myelography with an absorbable agent. *J Bone Jt
Surg* 47 (1965) 397
- INTAM L, SCHÖTTFLOM R, LÖNNERSTROM T and ZIGMOND M. Lumbal myelografi med
Conray Meglumum 282. (In Swedish) *Läk Tidsn* 67 (1970) 3185
- LEHTINEN E and SEPPÄNEN S. Side effects of Conray meglumine 282 and Dimer N in lumbar
myelography. *Acta radiol Diagnost* 12 (1972) 12
- LUNDLÖF K. Complications of myelography by alcohol. *Acta radiol* 28 (1947) 69
- MILROD D. Lumbar and sacral compression radiculitis (herniated lumbar disc syndrome).
New Engl J Med 254 (1956) 243
- PANTER K. Über Komplikationen und Gefahren bei der Alkohol Myelographie. *Dtsch med
Wochr* 78 (1953) 937
- PRÄHTHOLM J and LESTER J. Water soluble contrast lumbar myelography with meglumine
isothalamat (Conray). *Brit J Radiol* 43 (1970) 303
- and OLGAARD K. Comparative histological investigation of the sequelae of experimental
myelography using sodium methiodal and meglumine isothalamat. *Neuroradiology* 4
(1972) 14
- RIDENBERG C and WERNBERG E. Late sequelae following lumbar myelography with water
soluble contrast media. *Acta radiol Diagnost* 14 (1973) 507
- SODERBERG L, SJÖSTRÖM S and LARSSON P. Neurological complications following myelo-
graphy with water soluble contrast medium. *Acta orthop scand* 28 (1958) 220
- ZETTLER E. Myelographie mit einer neuen Kontrastmittelauspension. *Ergebn med Radiol*
2 (1969) 43

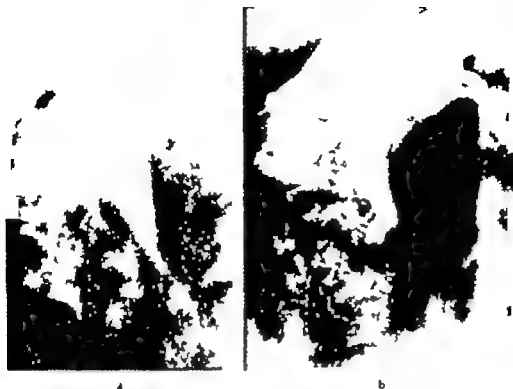


Fig. 1 Right renal carcinoma. a) Renal arteriography b) Angiotomography

Results

Of the 38 patients 9 were considered to have renal carcinoma, 29 cysts while the remaining 9 patients had other renal lesions. The diagnosis of carcinoma was verified in 8 cases by microscopy, usually both by fine needle biopsy and later by examination of the specimen after nephrectomy. In one patient microscopic verification was not obtained as this patient had rapidly increasing pulmonary metastases and operation was considered meaningless.

The benign renal cysts were usually single but in some cases multiple, often located in both kidneys. The smallest cyst, verified by puncture, had a diameter of about 4 cm, but defects with a diameter of about 2 cm were observed on some scintigrams. In 14 patients the diagnosis of cyst was verified either by angiography with demonstration of round well circumscribed avascular areas (5 patients) or by percutaneous puncture with injection of contrast medium (9 patients).

years. The predominance of old males depended on the fact that most patients were admitted from the urologic clinic, where the frequency of patients with prostatic disturbances was high.

Method

All patients were examined with a Nuclear Chicago Pho Gamma III HP equipped with a tape recorder (direct store system) and a persistence oscilloscope. The examination was performed in two stages. First the circulation in the kidney with the possible lesion was recorded and then scintigrams of both kidneys were obtained in different projections.

As a rule a cannula was inserted into a brachial vein before the examination. The patient was placed prone with the collimator of the scintillation camera centred on the aorta and the possibly diseased kidney. Its position had previously been determined on a roentgen film. Ten mCi $^{99}\text{Tc}^{\text{m}}$ DTPA (Renotec) or ^{51}Cr iron ascorbic acid complex were rapidly injected and the cannula flushed with physiologic saline. The examination was performed while the patient held his breath in deep inspiration in order to avoid blurring. By this means the background activity from liver and spleen could also be diminished during the recording of the circulation. This was obtained on the video-tape during 60 s with a high sensitivity collimator.

The video tape was then replayed and the circulation documented by sequential views, usually with an interval of 5 s. Immediately afterwards a static scintigram was taken (300 000 counts) the patient lying exactly in the same position. Scintigrams of the two kidneys were then taken 1 to 3 hours after the injection, depending on the renal function. During the recording the patient was instructed to breathe with a shallow respiration in order to diminish the respiratory movements of the kidney.

Different types of collimators were used: high resolution, high sensitivity and pinhole collimators. In some cases the collimator was tilted about 15° medially toward the kidney for better demonstration of defects in the renal parenchyma.

The perfusion of the kidney was evaluated from the sequential views; the function of the renal parenchyma was assessed by the accumulation of the isotope on the scintigrams.

A renal cyst was considered to be present in those cases where a defect in the renal perfusion corresponded with a defect of the same size and shape on the static scintigram, i.e. a non-vascular region of the kidney without functioning parenchyma. A malignant tumour was diagnosed when the recording of the circulation demonstrated a region with increased activity compared to the surrounding tissue and decreased accumulation on the static scintigram, i.e. increased vascularity without functioning parenchyma.



Fig. 3 Renal scintigraphy with tumoroph

The scintigraphically diagnosed renal lesions considered as cysts were not further examined in 6 patients. These were mainly old patients with prostatic disease considered non operable.

The scintigraphic diagnosis was erroneous in two patients. They had renal mass lesions which scintigraphically were considered to be well circumscribed areas with poor vascularization, similar to cysts. At percutaneous puncture, however, it was not possible to obtain any fluid. On the contrary malignant cells were aspirated from the mass at fine needle biopsy. Nephrectomy was performed and the malignant tumours were in both cases necrotic in the center which explained the similarity to cyst on the scintigram.

Seven patients had other renal abnormalities than carcinoma or cyst. One of these patients had in the lower pole of one kidney a bulge similar to a tumour. At scintigraphy no abnormality could be detected. Previously a nephrolithotomy had been performed and the bulge was probably a postoperative deformity.

At urography of another patient with prostatic lesion a kidney without function was found. No circulation through the kidney could be detected at

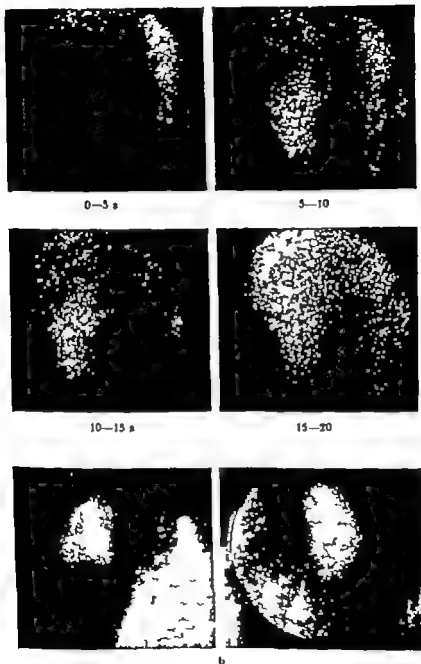


Fig. 1. Same case as in Fig. 1. a) Circulation in right kidney recorded with 10 mCi ^{99m}Tc -DTPA. Interval of 15 s between each sequential image. b) Scintigraphy of both kidneys one hour after injection. 300 000 count high resolution collimator.

scintigraphy and an obliteration of the renal artery was considered probable. At nephroangiography however a very small artery could be demonstrated and at renal phlebography veins in a capsule of a hydronephrotic kidney could be demonstrated. An enlarged prostatic gland had caused an obstruction to the urinary outflow from the kidney thus producing the hydronephrosis. Following the atrophy of the renal parenchyma the renal artery had diminished in width which explained that a clear understanding of the pathology could not be obtained at nephroangiography or scintigraphy.

If expansive lesions existed or not was difficult to decide at scintigraphy of another case because of impaired perfusion. Urography with tomography demonstrated an abnormality of uncertain nature in the medial part of one kidney. At percutaneous puncture a benign cyst was found. The clinical diagnosis was chronic glomerulonephritis which possibly could explain the impaired circulation.

In 4 patients with a similar urographic finding of small mass lesions at the renal hilum no abnormality could be detected at scintigraphy. Angiography was performed in two of these patients and by puncture in one. In all three cases nothing abnormal was found. Probably the urographic abnormality was caused by renal lipomatous with small lipomatous masses in or around the renal hilum.

Discussion

The scintigrams are not comparable with ordinary angiographic films in resolution. The scintigraphy has however many advantages over angiography and in some cases superior. Renal scintigraphy is not trying for old or deteriorated patients and is easily performed on out patients. Preparations as for radiography (laxatives or enemas) can be omitted as intestinal content does not interfere with the result of the examination.

Another advantage over angiography is that an arterial puncture and insertion of a catheter with the accompanying risk of injury to the arterial wall is avoided. The injection of the isotope should be done through an intravenous cannula, the risk of a perivascular injection is diminished and it allows a rapid injection of the isotope as a bolus. The prerequisite for a good demonstration of the arterial phase of the renal circulation is thus fulfilled. The amount of the injected, non-specific material is much less than at conventional angiography. Contrast media for radiography may cause serious allergic reactions but such complications are not known following isotope injections.

The radiation dose to the kidneys at scintigraphy with 10 mCi ^{99}Tc -iron ascorbic acid complex or ^{99}Tc -DTPA is about 1.2 and 0.4 rad respectively and the dose to the gonads 0.1 to 0.2 rad (GIMLETTE et coll 1972, HAUSER et coll 1970). This should be compared to the doses at nephroangiography where the

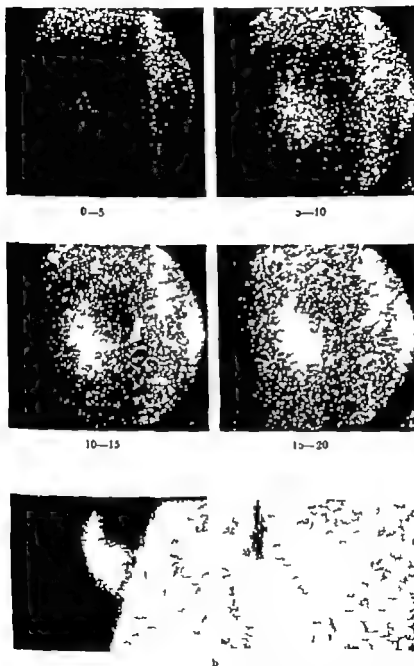


Fig. 4. Same case as in Fig. 3. a) Scintigraphy of right kidney recorded with 10 mCi ^{99m}Tc -DTPA. Interval of 5 seconds between each sequential image. b) Scintigraphy of both kidneys one hour after injection. 300,000 counts. High resolution collimator.

SUMMARY

The renal circulation and the function of the renal parenchyma have been analysed with ^{99}Tc -DTPA or ^{99}Tc -iron ascorbic acid complex in 38 patients with renal masses. The results have been correlated with angiography, percutaneous puncture and microscopy. The isotope method has allowed a differentiation between renal carcinomas and cysts. The method must be regarded as a complement to urography and may replace nephroangiography in selected cases.

ZUSAMMENFASSUNG

Die Nierenarteriellisation und die Funktion des Nierenparenchyms wurden bei 38 Patienten mit Nierenerkrankung mittels ^{99}Tc -DTPA oder ^{99}Tc -Eisen Ascorbinsäure Komplex untersucht. Die Ergebnisse wurden zur Angiographie, zur perkutanen Punktion und zur Mikroskopie korreliert. Die Isotopenmethode erlaubt es zwischen einem renalen Karzinom und einer Zyste zu unterscheiden. Die Methode ist als ein Komplement zur Urographie anzusehen und kann in geeigneten Fällen die Nierenangiographie ersetzen.

RÉSUMÉ

La circulation rénale et la fonction du parenchyme rénal ont été étudiées par ^{99}Tc -DTPA ou par le complexe acide ascorbique fer ^{99}Tc chez 38 malades présentant des masses rénales. Les résultats ont été confrontés avec l'angiographie, la ponction percutanée et la microscopie. Cette méthode isotopique a permis le diagnostic différentiel entre cancer du rein et kyste. Cette méthode doit être considérée comme un complément de l'urographie et peut remplacer la néphroangiographie dans des cas sélectionnés.

REFERENCES

- BLACK M. B., KIVO C. D. and SMITH D. R. Double isotope scintiphotography for differentiating between renal cysts and renal tumours. *J. Urol.* 98 (1966) 728.
 GIMLETTE T. M. D., SLEPPARD M. A., LITTLE W. A. and SQUIRE C. R. An experimental study of a technetium/iron complex for scintiscanning. *Brit. J. Radiol.* 45 (1972) 591.
 HALZER W., ATKINS H. L., NELSON K. G. and RICHARDS P. Technetium $^{99\text{m}}$ -DTPA: A new radiopharmaceutical for brain and kidney scanning. *Radiology* 94 (1970) 679.
 ROSENTHAL L. Radionuclide diagnosis of malignant tumours of the kidney. *Am. J. Roentgenol.* 101 (1967) 662.

doses are equal or often higher. Considering the radiation doses being rather equal at these types of examination the risk is about the same for the two methods.

Renal scintigraphy is not meant to replace urography but is to be regarded as a complement. By urography congenital or acquired renal abnormalities such as dysplasia, pyelonephritis, tuberculosis can be detected, the size of concretions determined and the wall of the urinary bladder demonstrated. This is not possible with renal scintigraphy which should be used only on specific indications for instance for differentiating between a carcinoma and a cyst. Renal scintigraphy can replace nephroangiography in such a case which is of particular value in old and deteriorated patients, in patients with disposition for pathologic bleeding (treatment with dicumarol or heparin) or in patients where difficulties at catheterization may be expected owing to vascular abnormalities. The scintigraphic results seem to be almost as reliable as the angiographic ones. A renal mass lesion with increased activity (vascularity) compared to the surrounding renal parenchyma is a malignant tumour with a high degree of accuracy with reservation for some rare conditions as vascular malformations and abscesses (carbuncle). In the latter case the clinical course usually indicates an inflammatory process. Poorly vascularized masses on the other hand may sometimes offer diagnostic difficulties. Necrotizing tumours are avascular centrally and often poorly vascularized in the periphery. This results in less activity in the lesion than in the surrounding tissue and the appearance is similar to a cyst. Two such cases exist in the material of 511 patients. At nephroangiography similar diagnostic difficulties may be encountered but the small vessels in the periphery of a tumour may be demonstrated with the aid of specific drugs. Cortical adenomas are poorly vascularized and may involve similar difficulties but no such tumours occurred in the material. The sensitivity of the method does not allow demonstration of filling defects with a diameter of less than 2 to 3 cm. The optimal resolution and the best possibilities to demonstrate small masses were found to be obtained by the pin hole collimator.

Tumour thrombi in the renal veins may be demonstrated by selective nephroangiography using large amounts of contrast medium. This is not possible at renal scintigraphy. The isotope may however be injected in the femoral vein and a tumour thrombus floating from the renal vein into the vena cava may thus be demonstrated. By combining isotope cavography and renal scintigraphy further diagnostic information may thus be obtained.

By the present method morphologic information on renal abnormalities was obtained. If a suitable radiopharmaceutical will be produced it is to be hoped that with the present method also the function of each kidney may be determined.

Table 1
Data on 9 patients in group I

Age yrs	Site of tumor	Size of tumor (cm)	Histology of tumor	Avil met
60 81	diffuse (right) lat (left)	diffuse (3 2.5 x 2)	poorly diff ca lobular ca	yes no
58	centr (left)	1 1 x 1	scirrhous ca	no
46 74 76	la (left) lat (left) lat (left)	2 x 2 1 1 1 diffuse	scirrhous ca cribriformous adenocarcinoma fibroadenoma	yes no no
80 76	centr (left) la (right)	2.5 x 1 x 2 1 2 x 1	scirrhous ca poorly diff adenoca	no no
71	lat (right)	4 x 3 1.5	scirrhous and medullary adenoca	yes

Knowledge of the spread of a neoplasm is essential if the operation or the postoperative irradiation techniques are to be modified. The main means of diagnosis for the parasternal lymph is scintigraphy. Most reports on parasternal scintigraphy have dealt with ^{199}Au colloid (ROSSI & FERRI 1966, SCHENK 1966, DIETHELM *et coll* 1967, SCHENK *et coll* 1966, MICHAÏLOV *et coll* 1968, HAZEN *et coll* 1968, 1969, ROSSI *et coll* 1968, SEIFERT & BETZNER 1970, MEYER, BURD & WILHELM 1971, GROS *et coll* 1969, 1972).

The use of $^{99}\text{Tc-S}$ colloid has been suggested by GORANSON *et coll* (1973) and GORANSON & JONSSON (1974). Two different techniques for parasternal scintigraphy have been used in experimental animals: a transabdominal technique with injection of the colloid into the peritoneal cavity (GORANSON *et coll* 1973); the other with injection of the colloid, mixed with hyaluronidase, into the soft tissue on both sides of the upright process (GORANSON & JONSSON 1974a). The purpose of the present investigation was to determine whether these two techniques could be used in human subjects. As no surgical information regarding the parasternal lymph nodes was obtained, comparison between the findings at scintigraphy and the histology of the lymph nodes was not possible.

Material and Methods All the patients had a palpable tumour of the breast and fine needle aspiration biopsy had verified carcinoma. Biopsy was performed before the scintigraphy in one patient. The $^{99}\text{Tc-S}$ -colloid was prepared ac-

PARASTERNAL SCINTIGRAPHY WITH TECHNETIUM 99m SULFIDE COLLOID IN HUMAN SUBJECTS

A comparison between two techniques

L. R. GORANSON and K. JOHANSSON

Lymph from the breast drains in two main directions to the axillary and parasternal lymph nodes. HULTBORN *et coll* (1955) demonstrated by the radioactive tracer technique that the lymphatic drainage from all parts of the breast is to both the primary groups of lymph nodes. The clinical implication of this is well documented in reports on the spread of carcinoma of the breast. ANDREASSEN *et coll* (1954) reported metastases in parasternal lymph nodes in a third of medially located carcinomas of the breast and in a tenth of lateral carcinomas of the breast. URBAN & MAJUMI (1971) observed axillary metastases in 47 and parasternal metastases in 10 per cent of a material of 725 patients operated on with extended radical mastectomy including resection of the parasternal lymph nodes. They noted only parasternal metastases with no involvement of the axilla in 8 per cent of the patients.

Submitted for publication 21 June 1973

Tabl 2

Data on 10 patients in group II

Age yr	Site of tumor	Size of tumor (cm)	Histology of tumor	Axill met
81	medial (right)	3 × 2.5 × 2	medullary ca	
59	lateral (right)	1 1 × 1	poorly diff ca	yes
49	central (Paget)	1.5 × 2.5 × 2	poorly diff adenoca	yes
70	lateral (left)	3 × 2.5 × 2	scirrhous ca	yes
91	central (right)	1.5 × 1.5 × 1.5	poorly diff adenoca	yes
88	central (left)	4 × 2.5 × 3.5	poorly diff scirrhous ca	no
65	lateral (right)	1.5 × 1 × 2	scirrhous ca	no
54	lateral (right)	5.5 × 3.5 × 3.5	poorly diff adenoca	yes
72	lateral (right)	1 1.5 × 2	ca with varying differentiation	yes
81	central (left)	9.5 3 × 3.5	poorly diff ca	yes

some time after injection of the colloid until transported to the gamma camera in a supine position. The time elapsing between injection and the registration on the camera was 15 to 240 minutes (Table 1) the uptake then being followed for 30 to 60 minutes. In two instances another examination was performed on the following day (17 hours after the injection). The activity in the abdomen was registered in 3 patients.

The second group (group II) consisted of 10 patients (Table 2). The ^{99}Tc S-colloid was concentrated to a volume of 1 ml with an activity of 500 μCi . 200 IU hyaluronidase were dissolved in the colloid. The colloid was injected into the soft tissues, half on each side of the xiphoid process, after which the skin was massaged for a few seconds. No local anaesthesia preceded the injection. In 5 patients the colloid was injected exclusively intra- and subcutaneously while in the remaining 5 patients part of the colloid was injected deep into the soft tissues as well.

The uptake in the parasternal lymphatics was followed 5 to 40 minutes after injection in one patient and the registration was repeated 16 hours later. The remaining patients were registered 110 to 200 minutes after injection. In 2 of these the examination was repeated 19 hours later and the registration carried out for 15 to 30 minutes.

Table 1 (cont)

Remarks	Registration (after inj.)	Findings (scintigraphy)
—	30–60 min	Two left and one right lymph node
cholecystect	13–63 min	No nodes Diffuse filling of mediastinum
20 yr ag	17 hours	17 hours no nodes
—	57–89 min	89 min no nodes 17 hours one left
—	17 hours	diaphragmatic node
—	43–83 min	No nodes diffuse filling of mediastinum
—	3–70 min	No nodes diffuse filling of mediastinum
—	100–130 min	Two lymph nodes laterally and right
—	30–60 min	supracardiacular fossa
cholecystect	100–160 min	No nodes Diffuse filling of mediastinum
7 yr ago	240–270 min	No nodes Diffuse filling of mediastinum
—		Two left sided lymph nodes and two right
—		diaphragmatic nodes

Findings that part of the tracer substance was caught the site of injection

According to PERSOON & NAVERSTEIN (1970) The uptake in the parasternal lymph nodes was recorded on a gamma camera (Nuclear Chicago Pho/Gamma III) with a 4000 channel or a pin hole collimator. The collimator was placed as close to and as parallel to the sternum as possible the distance between the sternum and the collimator was usually not more than 7 cm. The suprasternal notch and the xiphoid process were palpated and identified in all of the patients of both groups and these two points marked on the scintigraphy screen with a small radioactive source. The intercostal spaces were palpated and the radioactive source was used to identify the levels of the lymph nodes on the screen.

The first group (group I) consisted of 9 patients (Table 1). All the patients were examined in the following way: the patient lay supine. After careful cleaning of the skin of the abdomen to the left of the umbilicus 10 ml mepivacaine (Carbocain 1%) were injected in the subcutaneous tissues. A needle was then inserted through the abdominal wall with the tip in the free peritoneal cavity. The position of the tip was checked by fluoroscopy and the injection of a small amount of water-soluble isopaque. Ten ml ^{99m}Tc -S colloid with an activity of 500 μCi were injected into the free peritoneal cavity; no drugs were added to the colloid. The needle was rinsed with 10 ml saline and then withdrawn. If the condition of the patient permitted she turned and lay prone for

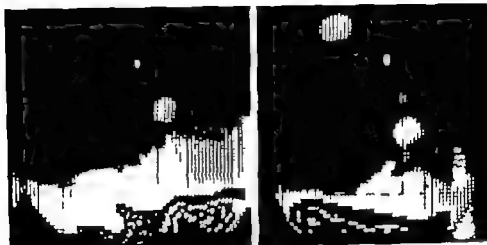


Fig. 1. Parasternal scintigraph with transabdominal technique. The suprasternal notch and the xiphoid process are marked by sharp dots. a) Two lymph nodes on the left side and one on the right side filled with tracer. b) Lymph nodes on both sides of the midline filled with tracer. A group of lymph nodes in the right supraclavicular fossa are also filled.

Discussion

Different methods have been published for the detection of lymph node metastases in the parasternal region. HANDLEY & THACKERAY (1949, 1954) described biopsy of these nodes. MASSOUD *et coll.* (1964) reported a series where tomography was performed in patients with induced pneumomediastinum. Transsternal phlebography is another possibility (CHERNOMORDEKOVA *et coll.* 1972). KETT *et coll.* (1970) described a method for direct lymphography of lymph vessels from the breast, but the method is not exclusively valid for the parasternal lymphatics.

Experimental investigations (CANNONHAM 1922, HELD 1932, SIVER 1944, COURTICE *et coll.* 1953, SALDEEN 1963, OLIN & SALDEEN 1964, GORANSON *et coll.* 1973) indicated that particles, macroproteins, blood corpuscles, thorotrast and ^{99m}Tc -S-collloid are absorbed from the peritoneal cavity through lymphatics in the diaphragm, draining to the parasternal lymph vessels. The findings were confirmed in one human subject by ATKINS *et coll.* (1970) who discovered tracers in mediastinal lymph nodes following the injection of technetium collloid into the peritoneal cavity. The transabdominal method has not earlier been used for clinical evaluation of the parasternal lymph nodes. The present results have proved that the technique is applicable in human subjects as well as in rabbits although this method has several disadvantages. One is the need of equipment for fluoro-

Tabl 2 (cont)

Registration after injection	Findings in scintigraphy
5-40 min	After 40 min no lymph nodes
16 h 15 min-16 h 30 min	After 16 hours four right and one left lymph node
130-150 min	One left and two right lymph nodes
130-145 min	One lymph node in right pectoral group
170-180 min	Two right lymph nodes
130-14 min	No lymph nodes
108-145 min	Three right and one left lymph nodes
180-200 min	No lymph nodes
19 h 30 min-19 h 4 min	One lymph node on each side
180-210 min	Two left lymph nodes
180-190 min	
200-220 min	
19 h 20 min-19 h 30 min	Three right and one left node

Results

Parasternal lymph nodes could be identified in 3 patients in group I (Table 1). In 2 of these the lymph nodes were observed on both sides of the sternum and in one in the supraclavicular fossa as well (Fig. 1) while in the third patient 2 nodes were seen on the contralateral side of the carcinoma. In the remaining 6 patients diffuse filling of radioactive colloid in the mediastinum was noted but no parasternal lymph nodes could be identified. Right-sided diaphragmatic lymph nodes (ROUVIERE 1932) were present in 2 patients. In the 3 patients in whom the activity in the abdomen was registered a great part of the colloid injected had accumulated at the site of injection. In 2 of these patients the parasternal lymph nodes were filled with tracer.

Uptake in parasternal lymph nodes was present in 7 out of 10 patients of group II in 5 bilaterally (Fig. 2) and in the remaining 2 patients unilaterally. In one patient the uptake was registered in one lymph node considerably to the right of the sternum - presumably in the medial pectoral group. No lymph nodes were evident in the remaining 3 patients.

used but Tc^{99} serum albumin has also been employed (SCHENK *et coll* 1966). The radiation dose locally absorbed is high when ^{199}Au is used for scintigraphy (HAUSFELD *et coll* 1969; HERTING *et coll* 1970) and radiation necrosis of the skin at the site of injection has been reported (HAAS *et coll* 1970). The physical properties of technetium are much more favourable than those of ^{199}Au : its half life is only 6 hours and as there is no beta radiation the locally absorbed radiation dose is much lower.

Experience in rabbits (GORANSON & JONSSON 1974 a) suggested that the absorption from the site of injection to the parasternal lymph nodes could be observed within 30 minutes or less. However the first patient examined with this technique failed to have any lymph node filling during 40 minutes after injection. However a faint filling was noted after 16 hours. The short half life of the tracer substance was thus of negative value. The absorption was registered 2 to 3 hours after injection in the patients who followed: this seemed to be the ideal time. The repeat examinations in 2 patients at 19 hours produced no further information.

The subcutaneous technique necessitates mixing the colloid with hyaluronidase to obtain maximal absorption in the parasternal lymph nodes (GORANSON & JONSSON 1974 a); this is not required however with the transabdominal technique (GORANSON *et coll* 1973). All patients of the present series have been verified with fine needle aspiration biopsy before the scintigraphy, but according to experiments (GORANSON & JONSSON 1974 b) such minor trauma of the thoracic wall does not affect the scintigraphy. All patients, except 2 examined with the subcutaneous technique, had radioactive tracer in parasternal lymph nodes indicating that the technique is more useful than the transabdominal one. The interpretation of the scintigrams thus obtained is difficult. The normal anatomic variations of the parasternal lymph nodes are considerable both in number and position (STRIBBE 1918). An investigation with parasternal scintigraphy in 25 healthy subjects demonstrated these wide variations (MEYER-BURE & WILHELM 1971): lymph nodes most commonly appeared in the second or third intercostal spaces.

The poor resolution in scintigrams permits no detailed examination of single lymph nodes as for instance in lymphography. The only sign of metastases presented by lymph scintigraphy is blocking of the lymph flow and it has been claimed that non filling of a lymph node chain is proof of metastases. Three patients of the present material had an uptake of tracer in unilateral parasternal lymph nodes. The carcinomas of these patients were ipsilateral to the non filled side which may indicate parasternal metastases. In the investigation of MEYER-BURE & WILHELM, however, healthy subjects also had non filling of the parasternal lymph nodes in some cases.

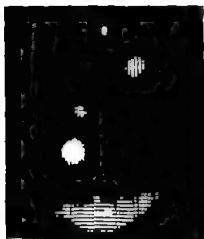


Fig 2 Parasternal scintigraphy with the subcutaneous technique. The suprasternal notch and the xiphoid process marked by sharp dots. T = right and one left lymph nodes filled with tracer.

scopy in order to ensure that the colloid is injected into the free peritoneal cavity. Although this was carefully controlled the tracer failed appreciably to spread from the site of injection in at least 3 patients; the omentum usually seemed to hinder the correct injection into the peritoneal cavity and the colloid was presumably trapped in the omentum. However in 2 of the 3 patients, parasternal lymph nodes could be identified indicating that some tracer substance was injected into the free peritoneal cavity and was sufficient to be absorbed and outline parasternal lymph nodes.

Another disadvantage with the transabdominal technique is that the patients who are mostly elderly cannot be moved about to improve the absorption; it is of course easy to place a rabbit prone with the chest low. Most of the patients in the present series were lying supine with the head and chest high because of cardiac failure or general weakness, a position that obviously does not enhance the absorption. Two of the patients in group I had been operated upon with cholecystectomy several years previously. Neither had any filling of lymph nodes. The manner in which an abdominal operation affects the absorption capacity of the diaphragm is not obvious; therefore the injection must be even more carefully controlled because of the risk of adhesions secondary to the previous operation. Our experience of the transabdominal technique is thus discouraging.

The subcutaneous technique with injection of tracer on both sides of the xiphoid process or behind the process in the midline has been the method most often employed for the parasternal lymph nodes. The technique has several advantages: there is no need for fluoroscopy equipment and the position of the patient does not influence the examination. Au colloid has been the substance most

REFERENCES

- ANDREASSEN M, DAHL IVERSEN E and SØRENSEN B. Glandular metastases in carcinoma of the breast. Results of a more radical operation. *Lancet* 266 (1954) 176
- ATKINS H L, HAUSER W and RICHARDS P. Visualization of mediastinal lymph nodes after intraperitoneal administration of ^{99m}Tc Sulfur colloid. *Nucl Med (Stuttg)* 9 (1970) 275
- CHERNOMORDIKOV M F, DEZMARSKY L Y, KJHOLDS S A and SELEZNEV I K. Limits and possibilities of transsternal phlebography for detection of metastases in the internal mammary lymph nodes. *Radiology* 107 (1972) 291
- COURTICE F C, HARDING J and STEINBECK A W. The removal of free red blood cells from the peritoneal cavity of animals. *Aust J exp Biol med Sc* 31 (1953) 215
- CLYNEHAM R S. Studies in absorption from serous cavities. IV. On the passage of blood cells and granules of different sizes through the walls of the lymphatics in the diaphragm. *Amer J Physiol* 62 (1927) 248
- DIETHELM L, BUCHHEID W, HAAS J P and WOLF R. Erweiterung der Diagnostik des Mammakarzinoms mit Hilfe von Isotopen. *J Radiol Électrol* 48 (1967) 677
- GROS C, VERONESI R, BECKM P et TRUCIOT M. Place actuelle de la lymphographie isotopique dans l'exploration du cancer du sein. *J belge Radiol* 55 (1972) 59
- , VERONESI C, SOLITE J et CHATEAU D. Lymphographie isotopique des chaînes mammaires internes. *J Radiol Électrol* 50 (1969) 168
- GORANSON L R and JONSSON K. a. Scintigraphy of the parasternal lymphatics in the rabbit using technetium 99m sulfide colloid. *Acta radiol Diagnosis* 15 (1974) 169
- (b). External factors affecting parasternal scintigraphy with technetium 99m sulfide colloid. *Acta radiol Diagnosis* 15 (1974) 508
- and OLIN T. Transsternal roentgenologic and scintigraphic lymphography of the central mediastinum with Thorotrast and ^{99m}Tc S colloid in the rabbit. *Acta radiol Diagnosis* 14 (1973) 3
- HAAS J P, BUCHHEID W and WOLF R. Zur Frage der Strahlenbelastung der Injektionsstelle bei der Lymphknoten skintigraphie mit kolloidalem ^{99m}Tc . *Radioaktive Isotope in Klinik und Forschung* Band 9 S. 405 Urban und Schwarzenberg München Berlin Wien 1970
- HANDLEY R S and THURGOOD A C. The internal mammary lymph chain in carcinoma of the breast: study of 50 cases. *Lancet* 2 (1949) 276
- Invasions of internal mammary lymph nodes in carcinoma of the breast. *Brit med J* 1 (1954) 61
- HAUSER W, ATKINS H L and RICHARDS P. Lymph node scanning with ^{99m}Tc Sulfur colloid. *Radiology* 9 (1969) 1369
- HELD A. Die Resorption von kolloidalem Thorium (Thorotrast) in der Bauchhöhle. *Z ges exp Med* 80 (1932) 819
- HINTIC S E, BUCHLER FREDRIKSEN P, JACOT T and JEFFERSON P. Lymph node scanning with colloidal radioactive gold. *Acta radiol Diagnosis* 10 (1970) 359
- HULTBORN K A, LARSON L G and RADWILLT I. The lymph drainage from the breast to the axillary and parasternal lymph nodes studied with the aid of colloidal Au. *Acta radiol* 43 (1953) 32
- KAZEM I, ANTONIADIS J, BRADY L W, FALET D S, CROLL M N and LIGHTFOOT D. Clinical evaluations of lymph node scanning utilizing colloidal gold 198. *Radiology* 90 (1968) 905
- , BRADY L W, CROLL M N, FALET D S and WOLFERTH C C. The parasternal lymph node scan as a prognostic test in breast carcinoma. *Radiology* 91 (1969) 617

Another group difficult to interpret correctly is the one illustrated in Fig. 1 a with filling of a lymph node in the 4th or 5th intercostal spaces, while the rest of the lymph node chain is not outlined. The other type of scintigram with filling of one or 2 lymph nodes in the first or second intercostal spaces (Fig. 2) suggests a normal lymph flow with no blocking. The bilateral filling of lymph nodes (Fig. 1 b) also indicates no blocking.

These difficulties in interpretation emphasize the need for further investigations to determine the correlation between the scintigram and findings obtained at surgery with a technique of extended radical mastectomy as described by URBAN & MARJANI (1971).

Acknowledgement

This investigation was supported by a grant from the John and Augusta Persson Foundation for Medical Research.

SUMMARY

Two techniques for parasternal scintigraphy with $^{99m}\text{Tc-S}$ -colloid in carcinoma of the breast are described. The first consists of the injection of the colloid into the free peritoneal cavity from where it is absorbed into the parasternal lymph vessels and nodes. In the second technique the colloid is mixed with hyaluronidase and injected subcutaneously on both sides of the xiphoid process. The technical aspects of these methods and the interpretation of parasternal scintigraphy are discussed.

ZUSAMMENFASSUNG

Es werden zwei Verfahren zur parasternalen Skintigraphie mit $^{99m}\text{Tc-S}$ Kolloid bei Karzinomen der Brust beschrieben. Das erste besteht aus der Injektion des Kolloids frei in den Peritonealraum, wovon es in den parasternalen Lymphgefäßen und -knoten abgelagert wird. Bei dem zweiten Verfahren wird das Kolloid mit Hyaluronidase gemischt und subkutan an beiden Seiten des Processus xiphoideus injiziert. Die technischen Aspekte dieser Verfahren und die Deutung der parasternalen Skintigraphie werden diskutiert.

RÉSUMÉ

Description des deux techniques d'oscintigraphie parasternale par un colloid $^{99m}\text{Tc-S}$ dans le cancer du sein. La première consiste dans l'injection du colloid dans la cavité péritonéale, d'où il est absorbé en l'ensemble lymphatique et les ganglions parasternaux. Dans la seconde technique le colloïde est mélangé d'hyaluronidase et injecté par voie sous-cutanée des deux côtés de l'appendice xiphoïde. Les auteurs étudient les aspects techniques de ces méthodes et l'interprétation de la scintigraphie parasternale.

AREA DISTORTION IN NARROW BEAM ROTATION RADIOGRAPHY

HJERIL ARNE SAMFORS and ULF WELANDER

In a panoramic image of the jaws produced with a rotating narrow beam there is no distortion at the centre of the object plane depicted without blurring in this plane the magnification factor in horizontal and vertical directions is the same. Inversely it may be maintained that the image is depicted without blurring in that very plane where there is no distortion and this statement is valid irrespective of the projection radius of the object (SAMFORS & WELANDER 1974). However outside the centre of the sharply depicted object plane different magnification factors are valid in the horizontal and vertical directions. The combined effect of the different horizontal and vertical dimensions in the panoramic image has been denominated as angle distortion (SAMFORS & WELANDER). Another effect arising from the same phenomenon is area distortion and has the result that the magnification factor of an area varies in the panoramic image the magnification factor depends on the position of the area in relation to the centre of the object plane which is depicted without blurring and distortion.

Due to several factors which are specific to the rotating narrow beam methods the magnification factor of an area is not directly proportional to the distance

Submitted for publication 16 April 1974

- LEITZ K, VARGA G and LUKÁCS L. Direct lymphography of the breast. *Lymphology* 1 (1970) 3
- MUSCOT G E, AWAD H K and EL KHARADLY M E A. The radiological investigation of axillary mammary lymph node metastases in breast cancer. *Clin Radiol* 54 (1964) 179
- NIETZBURG J and WILHELM U. Ergebnisse scintigraphischer Untersuchungen parasternaler Lymphknoten mit Au bei Normalpersonen. *Fortschr Röntgenstr* 115 (1971) 54
- NIKOLAYEV V, MITCHELL G and MLATOSCHIKOV C. Indirekt Isotopenlymphographie der parasternalen Lymphknoten mit radioaktivem Gold Au. *Radiobiol Radiother (Berl)* 9 (1968) 299
- OLIN T and BALDEEN T. The lymphatic pathways from the peritoneal cavity. A lymphangiographic study in the rat. *Cancer Res* 24 (1964) 1700
- PERSSON R II R and NIKOLAYEV V. Technetium 99m sulfide colloid preparation for scintigraphy of the reticuloendothelial system. *Acta radiol Ther Phys Biol* 9 (1970) 567
- ROSS R e FERRI O. La visualizzazione della catena mammaria interna con A^{99m} (In Italian). *Minerva med* 57 (1966) 1151
- — — TRIVELLINI G. La linfoscintigrafia mammaria interna con Au 198. Ricerca sperimentale ed impegno clinico (In Italian). *Arch ital Chi* 94 (1968) 33
- ROUVILLAS H. Anatomie des lymphatiques de l'homme. Masson & Co. Paris 1932
- SALDEEN T. Experimental studies on spread of Rous sarcoma in rats. *Acta path microbiol Scand Suppl* 162 1963
- SCHROCK P. Scintigraphische Darstellung des parasternalen Lymphsystems. *Strahlentherapie* 130 (1966) 504
- — — KUM WICKEL K and BECKER J. Die Scintigraphie des parasternalen Lymphsystems. *Nucl Med (Stuttg)* 5 (1966) 388
- SEIFERT J and BIERCKER J. Die indirekt parasternale Lymphscintigraphie beim Mammakarzinom. *Fortschr Röntgenstr* 115 (1970) 457
- SODER P H. The drainage of particulate matter from the peritoneal cavity by lymphatics. *Anat Rec* 88 (1944) 175
- STARR E P. The internal mammary lymphatic glands. *J Anat* 52 (1918) 257
- URMAN J A and MARJANI M A. Significance of internal mammary lymph node metastases in breast cancer. *Amer J Roentgenol* 111 (1971) 130

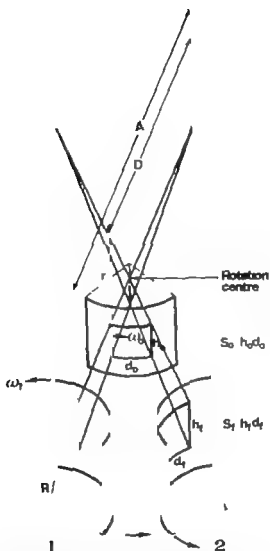
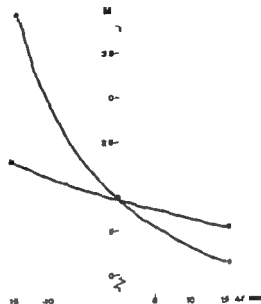


Fig. 1 Schematic drawing of the exposure of an area S in curved object by means of rotating narrow beam and moving film. Two positions are represented between which continuous movement takes place when the object is exposed.

Fig 2 The magnification factor of area as a function of Δr increment Δr and the object projection radius r . The functions are plotted for the anterior rotation centre $z = 28$ mm (●) and mean blur of the projection radius in the lateral rotation centre $z = 96$ mm (■) in the Orthopaedic tomograph 3. For object projection radius $r > 96$ mm but < 96 mm the magnification factor varies continually in the interval between the illustrated functions. The functions intersect the plane in the object which is depicted without blurring and distortion are distortion occurs outside this plane.



$$d_i = \frac{d_o R \omega r}{(r + \Delta r) \omega_o} \quad (1)$$

$$h_i = \frac{h_o A}{D + \Delta r} \quad (2)$$

An area in the object S_o is depicted in the image as $d_i h_i$. From equations (1) and (2) the following is thus obtained

$$S_i = \frac{h_o d_o A R \omega r}{(D + \Delta r) (r + \Delta r) \omega_o} \quad (3)$$

In rotating narrow beam methods one plane in the object is depicted without blurring and this occurs when

$$\frac{R \omega r}{r \omega_o} = \frac{A}{D}$$

From equation (3) a simplified expression is therefore obtained by substitution

$$S_i = \frac{h_o d_o A r}{D(D + \Delta r) (r + \Delta r)} \quad (4)$$

$h_o d_o$ is the area in the object S_o . An expression for the magnification factor may thus be obtained from equation (4)

$$M = \frac{S_i}{S_o} = \frac{A^2 r}{D(D + \Delta r) (r + \Delta r)} \quad (5)$$

focus to object and focus to film as in an ordinary central projection. It was therefore considered of interest to calculate the area distortion in narrow beam methods which does not seem to have been analysed mathematically previously.

The mathematical expressions were deduced using the model for narrow beam rotation methods presented by WELANDER (1974).

Area distortion

Definitions (See Fig. 1)

- h_o = vertical distance in the object
- h_t = length of the distance h_o projected on the film
- d_o = horizontal distance in the object
- d_t = length of the distance d_o projected on the film
- S_o = area in the object, $h_o d_o$
- S_t = size of the area S_o projected on the film $h_t d_t$
- M_s = magnification factor S_t/S_o
- r = distance from rotation centre of the beam to the centre of the object plane depicted without blurring 'object projection radius'
- R = film radius
- ω_o = angular velocity of the beam in the object
- ω_t = angular velocity of the film
- D = distance tube target to object
- Δ = distance tube target to film

Deduction In the horizontal plane the length in the image of a distance in the object is

$$d_t = \frac{d_o R \omega_t}{r \omega_o}$$

and in the vertical plane the length in the image of a distance in the object is

$$h_t = \frac{h_o \Delta}{D}$$

If the distance from the rotation centre of the beam to the centre of the object plane which is depicted without blurring r is given an increment Δr the distance between the tube target and the object D receives the same increment. Thus when the object position differs from the object projection radius the following distances are valid in the horizontal and vertical planes respectively

projection radius. However, the factor varies when an area in the object does not coincide with the plane depicted without distortion and blurring. When the object projection radius is given a positive increment, that is when the object is positioned in front of the distortion free plane, the magnification factor decreases. When the object projection radius is given a negative increment that is when the object is positioned behind the distortion free plane, the factor increases. The variation of the magnification factor is most marked when the object projection radius is small. For example, in the frontal rotation centre of the Orthopantomograph 3 the magnification factor will increase by more than 20 per cent when an area is displaced 5 mm behind the distortion free plane and it will decrease by more than 15 per cent when the area is displaced 5 mm in front of the distortion free plane. The figures valid for the lateral rotation centre are markedly smaller, about 5 per cent in both cases.

The fact that the magnification factor of an area varies depending on its position in relation to the object projection radius in rotating narrow beam methods depends on different horizontal and vertical length dimensions in the image. The conclusion must be that assessments of both the morphology and the size of structural details of the object must be made with some caution in a panoramic image, especially in the frontal region but to a certain degree also in the lateral regions (Fig. 3). However, together with distortion phenomena, blurring of the image occurs when the object does not coincide with the object projection radius. To a certain extent the blurring may be used to indicate the reliability of the image with respect to distortion, but it should be observed that there is a zone on both sides of the sharply depicted and distortion free object plane where the blurring of the image is negligible but where the distortion phenomena are evident.

SUMMARY

An image exposed with rotating narrow beam methods is free from distortion at the centre of the object plane which is depicted without blurring. Outside this object plane the magnification factor is different in the horizontal and vertical directions causing distortion of the image and a variable magnification factor of an area. The variation of this magnification factor in this report called area distortion has been calculated mathematically. From the mathematical expressions functions have been obtained which are valid for the Orthopantomograph 3.

ZUSAMMENFASSUNG

Ein mit den Methoden eines engen rotierenden Strahls exponiertes Bild ist im Zentrum der Objektebene, die ohne Unschärfe abgebildet wird, frei von Distorsion. Ausserhalb dieser Objektebene ist der Vergrösserungsfaktor in der horizontalen und vertikalen Richtung unterschiedlich, wodurch eine Distorsion des Bildes und eine beträchtlicher Vergrösserungs-

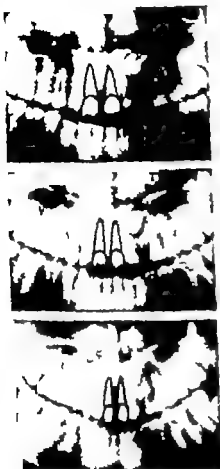


Fig. 3. The size of the teeth varies with the position of the object—real distortion. Object position towards the rotation centre (top), correct position (middle) and away from the film (bottom).

From equation (5) the variation of the magnification of an area, the area distortion in rotating narrow beam methods may be calculated. With the values for the object projection radius and for the target to object and target to film distances that apply in the Orthopantomograph 3 the functions illustrated in Fig. 2 will be obtained.

Discussion

The magnification factor of an area which coincides with the object plane depicted without blurring is 1.8 in the Orthopantomograph 3. This is the square of the magnification factor of the horizontal and vertical dimensions in the object plane. The magnification factor is independent of the object

COMBINED THERMOGRAPHY AND ISOTOPE SCANNING IN THYROID PATHOLOGY

G. GALLI, D. SALVO, I. TRONCONI and G. DE ROSSI

The thyroid gland is considered an ideal organ for thermographic examination both because of its superficial position and its rich vascularization. It is therefore surprising that so few have been interested in this field and that results obtained have been contradictory. Both GROS ET COLI (1961, 1968) and VAUNEL were pessimistic, pointing out the unreliable results and the difficulty of interpretation. The neck configuration and the superficiality of its larger vessels are limiting factors.

On the other hand, HEYRMA VAN VOSS (1966) and SAMUELS (1972) had a more positive attitude. The latter has described 50 cases, mentioning an 85 to 95 per cent positive correlation between thyroid disease and thermographic results and stressing the value of the method in the differential diagnosis of cold nodules revealed in thyroid scans.

The present work is a report on 125 thyroid examinations in which an apparatus obtaining simultaneously a thermogram and an isotope scan was used.

Method. Recordings were carried out with an accessory (MT-4 Magnatherm) connected to the collimator of the scanner (Fig. 1). The Magnatherm consists

Submitted for publication 24 November 1977

faktor eines Gebietes hervorgerufen wird. Die Schwankung dieses Vergrößerungsfaktors, die in diesem Bericht *Distortion des Gebietes* benannt wird, wurde mathematisch berechnet. Aus diesen mathematischen Ausdrücken wurden Funktionen erhalten, die für den Orthopantomograph 3 Gültigkeit haben.

RÉSUMÉ

Une image prise par des méthodes utilisant des faisceaux étroits tournants n'a pas de distortion au centre du plan objet qui est représenté sans flou. Hors de ce plan objet le facteur d'agrandissement est différent dans les directions horizontales et verticales, donnant lieu à une distortion de l'image et à un facteur d'agrandissement variable pour une surface. La variation de ce facteur d'agrandissement, appelée dans ce travail *distortion de surface*, a été calculée mathématiquement. Les expressions mathématiques ont permis d'obtenir des fonctions qui sont valables pour l'Orthopantomographe 3.

REFERENCES

- SILFVÉN K. A. and WELANDER U.: Angle distortion in narrow beam rotation radiography. *Acta radiol. Diagnos.* 15 (1974) 370.
WELANDER U.: A mathematical model of narrow beam rotation methods. *Acta radiol. Diagnos.* 15 (1974) 305.

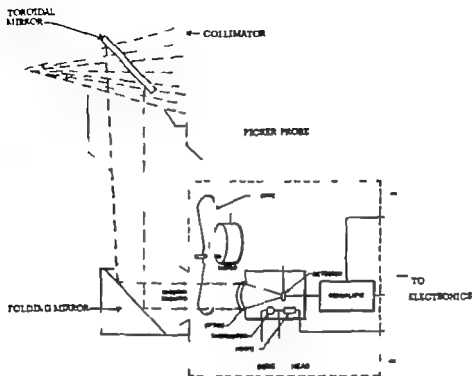


Fig. Diagram of the MT 4 Magnatherm optical system

verified by thermography. A difference in temperature exceeding 1.5 to 2°C in a hyperthyroid patient was sometimes observed.

Wider experience should make it possible to obtain statistical correlations between increased temperature values and values for thyroid function tests. There is no doubt however that a thermogram can better establish and confirm the raised temperature in prethyroidism already well appreciated by the clinician in case of advanced exophthalmic goiter.

Hypothyroidism. In hypothyroidism the thyroid cannot be seen in the thermographic image obtained with a Magnatherm.

Thermography proved valuable in cases of pharmacologic interference after administration of iodine compounds, such as contrast media. With unaltered thyroid function the thermography was normal while the ^{131}I uptake and scan simulated hypothyroidism.

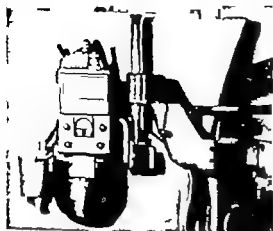


Fig 1 The Magnatherm connected to the scanner collimator

of a thermistor bolometer which receives infrared radiations through mirrors and is also connected to the scanner electronic system (Fig 2)

Cutaneous temperature is recorded both in centigrades and in Fahrenheit degrees; the apparatus can be set for three different levels of sensitivity according to the difference between cold and hot areas. The corresponding temperature gap is moreover divided into a range of eight different colours from red (hotter area) to white (colder areas). With a gap of 2 to 4 °C the change in colour in the image would then mark differences in cutaneous temperature of about 0.3 °C.

Fifteen minutes are allowed for the skin to equilibrate with the environment in a controlled ambient temperature of 20 °C before recording which takes five minutes.

Results

Normal thyroid In thermography with a Magnatherm the thyroid is represented as an area of slightly increased temperature (never superior to 1 to 1.5 °C) with unsharp borders inscribed in a relatively cold area corresponding to the trachea and larynx.

The thermographic image of the thyroid is sometimes hard to identify due either to the presence of rich subcutaneous fat or to a short thick neck. In such cases the thyroid could be easily confused with other hot areas such as the submentum region, the great vessels, the jugular and the supraclavicular fossa.

Hyperthyroidism Increased metabolism and greater vascularization observed in hyperthyroidism may give an increased cutaneous temperature which is re-

cutaneous temperature. The values were close to those recorded for hyperthyroidism and toxic adenoma. This relationship seems logical in view of the proliferative activity and the increased vascularization of a neoplastic disease. In contrast to Plummer adenoma, areas of reduced or low activity were obtained on isotope scanning.

Thermography gave equivocal results in benign tumours. Only three adenomas with no toxic characteristics were examined.

Discussion

The observations suggest the value of combined thermography and scanning mainly in the diagnosing of thyroid nodules.

With hyperfunctioning adenomas well diagnosed by clinical and isotope tests, thermography could prove of minor importance, while being of great usefulness in distinguishing cold areas on the scan due either to cysts or to benign substitutive processes from those due to malignant tumours. The cutaneous temperature is unaltered or lowered in benign growths while a definite increase in skin temperature is observed in malignant tumours.

The use of the Magnatherm could present valuable possibilities for analyzing and localizing even small growths. Thermography and isotope scan fit perfectly as they are carried out at the same time and with identical conditions and position of the patient.

A few limitations of thyroid thermography need to be considered, however. Nodules less than 2 cm may give no appreciable changes in a thermogram. Even lesions larger than this could hardly be seen when situated in marginal areas covered by the sternocleidomastoid muscles or close to the great vessels of the neck. If the thyroid is large, lesions close to or below the thoracic inlet may not be seen.

It should also be borne in mind that benign lesions give equivocal thermogram and the same could happen with poorly vascularized malignant tumours.

The limitations do not in our opinion affect the validity of the method but they emphasize the necessity of accuracy in evaluating results. Thermography is likely to become an essential aid in the diagnosis of thyroid lesions.

SUMMARY

A Magnatherm Picker apparatus permitting simultaneous thermography and isotope scanning has been used for examination of the thyroid. Thermography was valuable in the diagnosis of function alterations. Hyperthyroidism causes an increase of cutaneous temperature. Combined thermography and isotope scanning appeared useful for investigating non-functioning thyroid nodules while malignant tumours tend to increase cutaneous temperature. Cysts could give rise to areas of relative hypothermia. An increase in temperature was also seen in the toxic adenoma.

Table

Thermography in 31 patients operated upon for extra thyroid solitary nodules

Skin temperature	Histology	No. of cases
+	Toxic adenoma	5
	Carcinoma	6
	Follicular 1	
	Papillary 3	
	Indifferent 2	
±	Benign adenoma	1
	Benign adenoma	1
	Regional hyperplasia	1
—	Benign adenoma	1
	Toxic adenoma	1
	Cysts	1

Thyroid nodules The results are based on 31 patients who underwent operation (Table). The upper part of the Table refers to cases with increased cutaneous temperature (+) over the nodular formation and the lower part to those with a normal or relatively hypothermic thermogram (—). The middle part consists of two cases with a doubtful thermogram.

Plummer adenomas Out of 10 cases only 2 according to Gross & Vrousos (1966) gave a typical image with the so-called localized area of increased cutaneous temperature. Seven patients had a normal temperature and one diffuse hypothermia.

Our results on the other hand indicated increased temperature slightly wider than the corresponding nodule in 5 out of 11 toxic adenomas. The sixth case had no alterations in cutaneous temperature but histological examination presented a vast zone of necrosis following hemorrhage.

Cysts At operation 15 patients had cysts in the area corresponding to nodules. In every case the scan had areas of absent uptake and the thermogram areas of decreased cutaneous temperature.

In small cysts the decreased temperature was confined to the cutaneous area corresponding to the nodule while in the voluminous ones the hypothermia included besides the cyst also the skin covering the remaining thyroid parenchyma.

Tumours Six cases of histologically confirmed malignant tumours were thermographically tested. The thermogram demonstrated an evidently increased

NORMAL LYMPHOGRAPHIC VARIATIONS OF LUMBAR, ILIAC AND INGUINAL LYMPH VESSELS

ALF HOLBENSTVEDT

Obstruction of lymph vessel with collateral by-passing is a valuable sign in the diagnosis of metastases in the lymphatic system (HAIN et coll 1963 FLEISCH et coll 1964 1968 FLICH 1972 FRISCHMETER 1966 1972). Large totally infiltrated lymph node have however also been reported without concomitant alteration of the lymph flow (JACKSON 1967). Knowledge of the normal anatomical variations is a prerequisite for a satisfactory evaluation of collateral. Although the lymph vessel system is subject to innumerable variations (FLEISCH et coll 1968) probably unsurpassed by any other organ system (HUTTI 1972) some principles may be discerned.

While the normal and pathologic variations in the lymphographic appearance of the internal chest and thoracic duct have been thoroughly elucidated (WELSH & LEFDER 1964 WALLACE & JACKSON 1968 RACONTO & CORRU 1969 WORTIS & FROMMELT 1970 FLICH & CALEAZZI 1970 JACOBSSON 1972) less attention has been given to variations in the peripheral lymphatic trunks.

Material During the period February 1970 to March 1973 preoperative lymphography was performed in 300 consecutive patients with carcinoma of the uterine cervix stages Ib and II. The treatment consisted of radical hysterectomy

Submitted for publication 1 November 1973

ZUSAMMENFASSUNG

Ein Magna-therm Picker Apparat der die gleichzeitige Thermographie und Isotopen Scanning erlaubt wurde zur Untersuchung der Thyroidea eingesetzt. Die Thermographie war zur Diagnose von funktionellen Veränderungen von Wert. Hyperthyreoidismus hatte den Anstieg der Hauttemperatur zur Folge. Die mit der Thermographie kombinierte Isotopen Scanning erlaubte bei der Untersuchung nicht aktiver Knoten der Thyroidea zusätzlich während maligne Tumoren zu einer gesteigerten Hauttemperatur führten. Cysten zu Gebieten relativer Hypothermie. Eine gesteigerte Temperatur war ebenfalls bei malignen toxischen Adenomen zu sehen.

RÉSUMÉ

Un appareil Magna-therm Picker permettant simultanément la thermographie et la scintigraphie isotopique a été utilisé pour l'examen de la thyroïde. La thermographie présente un intérêt pour le diagnostic des altérations fonctionnelles. L'hyperthyroïdisme cause une augmentation de la température cutanée. L'association de la thermographie et de la scintigraphie isotopique paraît utile pour l'examen des nodules thyroïdiens inactifs, lorsqu'ils sont malins tendent à augmenter la température cutanée. Les kystes pourraient donner lieu des surfaces de relative hypothermie. Une augmentation de la température est constatée aussi dans des adénomes toxiques frustes.

REFERENCES

- GEORGE CH. BOUJUT P. and SCHMITZ J. L'exploration thermographique du corps thyroïde
J. Radiol. Électrol. 49 (1968) 791
— and VAUGHAN C. Thermography médicale. Presse méd. 74 (1966) 2902
HARRISON V. A. and VOGEL S. F. C. Thermographic studies of the thyroid gland. Bibl. radiol. 5 (1966) 201
LLOYD WILLIAMS H. Infra red thermometry as a tool in medical research. Ann. N.Y. Acad. Sci. 121 (1964) 99
SANDERS B. I. Thermography. A valuable tool in the detection of thyroid disease. Radiology 102 (1972) 53



Fig. 1



Fig. 2



Fig. 3



Fig. 4



Fig. 5



Fig. 6

(For legend see opposite page)

and pelvic lymphadenectomy 6 weeks after radium insertions. An average of 30.6 lymph nodes per patient were removed and examined histologically. The present investigation was based on the first 200 patients without lymph node metastases. A detailed description of the lymphographic methods used and the surgical procedure has been given by KOLBENSTÆDT & KNUDSEN (1974) and KOLBENSTÆDT & HOLSTAD (1974).

Results

Iliac lymph vessels. The external iliac lymphatics are divided into three chains according to the classic descriptions by CUNEO & MARCILLE (1901) and ROUVIERE (1932): they run on either side of and between the external iliac artery and vein. The names lateral, intermediate and medial chains were recommended at the International Symposium of Lymphology, Zurich 1966. At lymphography three main stems may be demonstrated (Fig. 1) but more often the vessels have an unsystematic, disordered appearance where the main trunks cannot be discerned. In the present material three main lymphatic trunks appeared in 41 per cent on the right side and in 37 per cent on the left. CHAVANNEZ *et coll.* (1967) reported a corresponding 35 per cent in 100 lymphographies.

Lymph vessels within the internal iliac regions (Figs 2-5) were demonstrated in 56 per cent on the right side and in 53 per cent on the left. These vessels sometimes proceeded posteriorly towards the lower part of the sacrum.

By-passes. All lymph nodes filled by injection into a lymph vessel in the foot from the inguinal region to the lumbar region may be by-passed. An inguinal by-pass (Fig. 3) has previously been described by FERSCHMÄTZER (1966) and KRYNORTH (1972). The former noted that such a lymph vessel usually ended in the most distally situated lateral external iliac node — the lateral lacunar node. This node has also been called the semilunar node, the appearance being due to fibromatous infiltration. The inguinal nodes, being the primary filter stations, often have similar appearances. The lateral lacunar node may thus often functionally be regarded as an inguinal node due to by-passing although anatomically belonging to the iliac group.

External iliac by-passes. (Figs 4-5) were observed in 7 patients (3.5 per cent). The vessels as a rule passed by the external iliac and the lower part of the common iliac region to some small lymph nodes along the iliac crest. They have been denominated lumbar vessel (FUCHS *et coll.* 1968) and *chaîne circonflexe iliaque* (ROUVIERE 1932).

Common iliac by-passes. (Figs 6-7) were observed twice. In both instances lymph vessels along the psoas major muscle passed by the common iliac region to lymph nodes on the dorsal and lateral surface of the psoas.



Fig 9a

Fig 9b

Fig 10

Fig 9 a) Right lateral inguinal loop b) Left lateral inguinal loop c) filling of lateral inguinal lymph nodes in the loops

Fig 10 c) intercostal loop in the 10th right intercostal space

space (Fig 10) and once in the 9th left intercostal space. In the latter case a small chain of intercostal lymph nodes was demonstrated. The thoracic duct was not obstructed.

A subpubic loop was revealed once (Fig 11). This loop just extended across the midline inferior to the symphysis pubis and led to filling of a right obturator lymph node. ARVAY & PILARD (1963) described a normal but exceptional lymph vessel crossing the midline along the pubic bones but superior to the symphysis pubis (*veine anatomique sus pubienne*).

Lymph vessels in connection with the obturator node. The French anatomists CUNEO & MARCILLE (1901) and ROUVIERE (1932) denominated the lymph nodes between the external iliac vessels and the obturator artery and nerve the medial or internal chain of the external iliac lymph nodes. The name obturator node is reserved for one or a few nodes along the peripheral branches of the obturator artery close to the obturator foramen. This node was only demonstrated in 5 patients (2.5 per cent). Unusual lymph vessels occurred in three of them (Figs 11-13); in one case (Fig 13) as a perivascular lymphatic.

Presacral anastomoses. The lateral sacral lymph nodes were demonstrated in 41 per cent of the patients but transverse presacral anastomoses (Fig 14) were only observed in 6 patients (3 per cent).

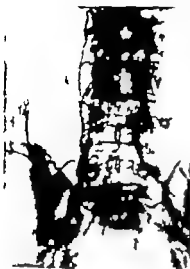


Fig 7



Fig 7b



Fig 8

Fig 7 a) Right common iliac and lumbar by pass b) A chain of lymph nodes along the lateral surface of the psoas major is filled

Fig 8 U usually lower right lumbar by pass A larger number of lymph nodes demonstrated on the left than in the right lumbar region

A right lumbar by pass (Fig 8) was reported by WIRTH (1966) and KERNOWITZ (1972). The latter reported a corresponding discontinuity — the right lower lumbar gap — in the chain of lymph nodes. Thus the right lumbar region may be defectively demonstrated following injection into a foot lymphatic, the consequence being that the lymphography often has to be supplemented by phlebography of the inferior vena cava and urography.

Blind loops. Lateral inguinal loops were observed in two patients (Fig 9). No lymph nodes were filled through these loops and no signs of lymphatic obstruction were present. Thus no reasonable explanation of the finding can be given.

Intercostal loops were also observed twice, once in the 10th right intercostal

Fig 1 The three normal iliac lymph vessel trunk: lateral, external and medial

Fig 2 Lymph vessels to the internal iliac lymph nodes. The vessels form a circle around the psoas, iliacus but no lymph nodes were found to operate

Fig 3 Inguinal by pass (→). The contrast medium flowed directly to the most caudal lateral external iliac node (the lateral lacunar node)

Fig 4 External iliac by pass or circumflex iliac branch usually by passing the external iliac and the most caudal common iliac lymph nodes. Node along the iliac crest is often filled in this case

Fig 5 Right iliac region. Numerous internal iliac lymph vessels and an external iliac by pass

Fig 6 Left common iliac by pass with lymph nodes at the psoas major muscle

Conclusion

The normal anatomic variations of the lymph vessels are numerous, and may appear as by-passes, blind loops, vessels to the obturator node or precrural anastomoses. Knowledge of these variations is necessary to avoid false diagnoses.

SUMMARY

Some lymphographic variations of the lumbar iliac and inguinal lymph vessels based on normal material of 200 cases are described.

ZUSAMMENFASSUNG

Einige anatomische Variationen des lumbalen und Becken-Lymphsystems bei einem Material von 200 Fällen werden beschrieben.

RÉSUMÉ

Description de quelques variations lymphographiques des vaisseaux lymphatiques lombaire iliaque et inguinaux basées sur une série de 200 cas normaux.

REFERENCES

- ARVAS N. and PARKER J. D. La lymphographie: étude radiologique et clinique des vases lymphatiques normaux et pathologiques. Masson & Cie Paris 1967.
- CLAVELLE C., PELLERIN D. and VALETTE M. La lymphographie dans les stades I et II du cancer du col utérin. Étude de 150 cas opérés et vérifiés histologiquement. J. Radiol. Électrol. 48 (1967): 117.
- CLAVELLE C. and MARILLIE M. Lymphographie des ganglions ilio-pelviens. Bull. Soc. anat. Paris 6 (1901): 659.
- CLAVELLE C. and J. B. The demonstration of an unusual combination of collateral channels during lymphography - a case report. J. Canad. Ass. Radiol. 20 (1969): 189.
- FAHRENBACH H. J. Die Lymphographie: Möglichkeiten und Grenzen der Metastasen-diagnostik beim weiblichen Carcinom (Geburtsh. u. Frauenheilk. 26 (1966): 125).
- Verbestimmung der einschließenden Metastasen-kriterien. Radiol. diagn. 5 (1972): 391.
- FAHRENBACH H. J. Fra die artspezifischen lymphographischen Metastasen-kriterien bei bestimmten Organumoren. Radiol. diagn. 5 (1972): 627.
- and BOOK HYDENTHUM C. Lymphography in the diagnosis of metastases with special reference to the carcinoma of the uterine cervix. Acta radiol. Diagnosis 2 (1961): 161.
- and GALLAGHER R. L. Die Röntgenanatomie des Ductus thoracicus. Radiologe 10 (1970): 180.
- ELIASSON J. W. and FAHRENBACH H. W. Lymphography in cancer. Springer Verlag Berlin Heidelberg New York 1968.
- HARRIS C. A., WALLACE S., JACKSON I. and DODD C. Lymphangiography in gynaecology. Am. J. Obstet. Gynec. 85 (1963): 734.



Fig 11 Right obturator lymph node (→) filled in subpubic loop extending across the midline inferior to the symphysis pubis



Fig 12 Right obturator lymph node close to the anterior abdominal wall filled in lymph vessels from the contralateral side

Lymph vessel displacement and pathologic lymphatics Tortuous arteries often displace lumbar and iliac lymph nodes and vessels (WERTH 1966 FUCHS et coll 1968). These displacements may have an appearance similar to that caused by tumours thus giving rise to differential diagnostic difficulties.

In patients with obstruction of the lymphatic flow a variety of lymph vessels have been described as collaterals. In the present normal material the following vessels were never encountered: dermal backflow (KJØRMOYTH et coll 1962), uterine or rectal collaterals (FUCHS et coll 1968), mesenteric, splenic or hepatic collaterals (CUNNINGHAM 1969 MARROVITS & BERGSON 1970), p-tineural sheath collaterals (WALLACE et coll 1964), abdominal wall collaterals to the axillary region (HARTOILL 1964). This supports the suggestion that all these collaterals have a pathologic significance. Trapping of oil droplets in emulsions through lymphovenous anastomoses (KJØRMOYTH 1972) was never observed.



Fig 13 Perivascular lymph vessels and right iliac and right obturator lymph node (→)



Fig 14 Left lateral sacral lymph node filled in pre-sacral anastomoses

APPEARANCE AND GROWTH OF EARLY CARCINOMAS OF THE COLON RECTUM

G. EDELLUND, C. LINDBLÖM and J. E. ROSENBERG

Polyps even with a diameter of less than 5 mm may be demonstrated by means of double contrast radiography of the large bowel (ANDREU *et coll.* 1955). This gave rise to the practical problem of distinguishing small benign polypoid tumours from malignant ones, but WELBY *et coll.* (1963), FROEL *et coll.* (1965) and WELBY (1967) reported some radiographic features indicating malignancy of such small lesions.

The intention of the present investigation was to examine in retrospect a series of patients with carcinoma of the colon rectum for preceding signs of polypoid lesions at the site where a carcinoma had later been diagnosed and to analyse the radiographic features of any such early lesion. This was possible because a recent investigation of 960 cases of carcinomas of the colon rectum (BERGE *et coll.* 1973) included a group of patients who had been examined on several occasions with double contrast radiography of the colon for several years before operation.

The intention was also to investigate the growth rate of tumours and the effect of delaying operation as judged from histologic stages of tumours, frequency of metastases and survival rate.

Submitted for publication 17 December 1973

- HARTSHILL J C Lymphography in the management of pelvic malignant disease J Obstet Gynaec Brit Cwlth 71 (1964) 835
- HITTE I Allgemeine Pathologie des Lymphgefäßsystems I Handbuch der allgemeinen Pathologie Band 3 Teil 6 S 457 Herausgegeben von H Hensen Springer Verlag Berlin Heidelberg New York 1972
- JACKSON W J A Lymphographic studies related to the problem of metastatic spread from carcinoma of the female genital tract J Obstet Gynaec Brit Cwlth 74 1967 39
- JACOBSON S I Clinical anatomy and pathology of the thoracic duct An investigation of 122 cases Almqvist & Wiksell Stockholm 197
- JENNINGS J B The lymphatics Diseases Lymphograp and lymph Edward Arnold London 1972
- ROSE C G and SUTTORF F A Vascular surgery Edward Arnold London and Williams and Wilkins Baltimore 1962
- KOENIGSMANN A and KAMMAYR O A method for lymphographic and histologic correlation Experience from 300 patients treated by pelvic lymphadenectomy Gynec Oncol 2 (1974) 9
- and KAMMAYR P Pelvic lymph node dissection under peroperative lymphographic control Gynec Oncol 2 (1974) 39
- MAROTTA P et BERGHOFF CH Valeur et limites de la lymphographie dans le cancer utérin Bull Soc Chirurgiens Paris 60 (1970) 381
- RAICINO V e COZZI F Quadri linfografici del dotto toracico in condizioni normali patologiche (I Italian) Radiol med (Torino) 55 (1969) 721
- ROCHER H Anatomie des lymphatiques de l'homme Masson Cie Paris 1937
- VAUGHAN JR M A TUCKER D PARKS R BLUM E BEYLAQUE M and RICHIE L Radiographic-pathologic correlation in the interpretation of lymphangiograms Radiology 80 (1963) 903
- WALLACE S and JACKSON L Diagnostic criteria for lymphangiographic interpretation of malignant neoplasia Cancer Chemother Rep 52 (1968) 121
- — DODD G D and GRIFFITH R H Lymphatic dynamics in certain abnormal states Am J Roentgenol 91 (1964) 187
- WENZELER H Das pathologische Lymphangiogramm des Ductus thoracicus Fortsch Röntgenstr 101 (1964) 573
- WIRTH W Zur Röntgenanatomie des Lymphsystems der abdominalen pelvischen und thoraxnahen Regionen 2 Teil Fortschr Röntgenstr 105 (1966) 636
- and FACHNITZOLD H Der Ductus thoracicus und seine Variationen Lymphographische Studie Fortschr Röntgenstr 112 1970 450

APPEARANCE AND GROWTH OF EARLY CARCINOMAS OF THE COLON RECTUM

G. EKELUND, C. LINDSTROM and J. E. ROSENBERG

Polyps even with a diameter of less than 5 mm may be demonstrated by means of double contrast radiography of the large bowel (ANDERLIN *et coll.* 1955). This gave rise to the practical problem of distinguishing small benign polypoid tumours from malignant ones, but WELIN *et coll.* (1963), FROEL *et coll.* (1965) and WELIN (1967) reported some radiographic features indicating malignancy of such small lesions.

The intention of the present investigation was to examine, in retrospect, a series of patients with carcinoma of the colon rectum for preceding signs of polypoid lesions at the site where a carcinoma had later been diagnosed and to analyse the radiographic features of any such early lesion. This was possible because a recent investigation of 960 cases of carcinomas of the colon rectum (BERGE *et coll.* 1973) included a group of patients who had been examined on several occasions with double contrast radiography of the colon for several years before operation.

The intention was also to investigate the growth rate of tumours and the effect of delaying operation as judged from histologic stages of tumours, frequency of metastases and survival rate.

Submitted for publication 17 December 1973

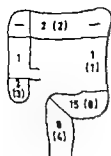


Fig. 1. Location of the 30 tumours. Figures within brackets indicate location of tumours overlooked at first examination.

Material and Methods The 950 cases of carcinoma of the colon rectum constitute 94 per cent of all cases diagnosed during life in the city of Malmö during 1958 to 1967 and treated at the Department of Surgery of Malmö Allmänna Sjukhus, the only one in the city (BERG *et al.* 1973). In this series, where the double contrast method had been used routinely for examinations of the colon, there were altogether 30 cases in which the diagnosis of carcinoma had been preceded by local abnormalities indicating a small polypoid tumour (6–26 mm in diameter). These patients, 22 men and 8 women, with a mean age of 66 years constitute the present material. In all of these 30 patients the colon rectum had been examined with the double contrast method 2 to 10 times, on the average 3 times, before operation. All films were examined for the signs described as characteristic of malignancy (WALLIN 1967, the Table). Growth rates were calculated from measurements of the largest diameter of the polyps measured on roentgenograms taken in the same projection. Histologic specimens from all cases were reviewed. The tumours were staged according to Dukes (1932) and the carcinomas were graded as being well, moderately or poorly differentiated.

Results

Small haemorrhages (12 cases) were usually the indication for the roentgen examination of the colon.

Table

Number of polypoid lesions with various features at first examination

More than 10 mm diameter	21
Irregular surface of the tumour	17
Basal height	8
Indication of base	6
Not at signs	4



b

FIG. 4. Woman aged 55 examined because of rectal bleeding. a) 4.9 mm \times 9 mm pedunculated polyp with irregular surface in the sigmoid colon. b) Five months later slight increase in size. c) After another 5 months 13 mm \times 17 mm. Histology: Moderately to poorly differentiated adenocarcinoma with invasion through the muscularis mucosae. Signs of a recurrence 156 months after operation.

Histology of the operative specimens revealed that all the tumours were carcinoma. Seven were still polypoid, 11 medallion shaped and 12 annular. One tumour was not operable and the diagnosis is based on autopsy instead. In 2 cases the carcinoma was confined to the lamina propria, in the other 28 it had invaded at least the muscularis mucosae. Nine patients were classified as A-cases (Dukes 1932) (tumour spread into the tissues of the bowel wall but not beyond the muscularis propria), 10 as B (tumour grown through the muscularis propria but not spread to lymph nodes), 8 as C (metastases in regional lymph nodes) and 3 cases had distant metastases. Of the 28 patients operated upon for cure, 13 later had developed distant metastases (on the average 30 months after operation).

Altogether 19/63% of the 30 patients were found to have metastases either at operation or at a later examination. Distant metastases were later found in 4 of the 7 cases classified at operation as belonging to group A. These 4 tumours were moderately or moderately to poorly differentiated. In one case the tumour was excised locally but it is doubtful whether the operation was radical.

The 5 year survival rate after operation was 37 per cent in the total material, in A-cases 49 per cent, in B-cases 60 per cent and in C-cases 30 per cent.

No correlation seemed to exist between the stage of the tumour at operation and the rate of growth or the duration of the observation time. The material is too small to permit statistical conclusions.



Fig 3 Man aged 55 examined because of rectal bleeding. a) An 8 mm \times 8 mm polyp of the sigmoid colon without signs of malignancy overlooked b) Nine months later 12 mm \times 15 mm. c) After another 16 months 15 mm \times 15 mm outline then irregular d) Sixty four months after the initial examination 18 mm \times 21 mm Histology: A polypoid moderately differentiated adenocarcinoma growing through the muscularis mucosae. Eighty-eight months later the patient died Autopsy: Primary liver cell carcinoma, no metastases from the carcinoma of the colon.

such characteristic indentation including one case where the polyp was less than 10 mm across.

None of these signs was present in 4 of the patients at the first examination (Fig 3).

Growth rate. During the observation period all tumours increased in size. Fig 2 reveals the size of each primary polypoid lesion and of the corresponding final carcinoma (in the last preoperative film). The mean linear diametric growth was 0.61 mm per month (range 0.06—2.00, median 0.52). The smallest carcinoma in this series was 13 mm \times 17 mm at operation (Fig 4).

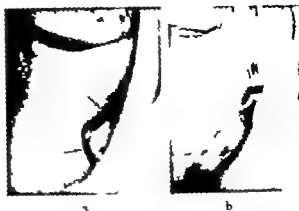


Fig. 1. Man, aged 45, with a history of bleeding from the rectum. The tumour was removed by sigmoidectomy. The specimen was fixed in formalin and sectioned. The tumour was 10 mm in diameter and 10 mm in length. The tumour was composed of a stalk and a head. The stalk was 5 mm in diameter and 5 mm in length. The head was 5 mm in diameter and 5 mm in length. The tumour was composed of a stalk and a head. The stalk was 5 mm in diameter and 5 mm in length. The head was 5 mm in diameter and 5 mm in length.



lesions than in benign ones (WELLS 1967). These signs are not unconditionally pathognomonic of malignancy. In the present series only carcinomas were included and the early appearance of the reported signs of malignancy on an average 3 years before operation analysed. The signs will be discussed briefly.

Size. The risk of a polypoid tumour being malignant rapidly increases when it is more than 10 to 12 mm in diameter (SPRATT & ACKERMAN 1960; LITTLING *et al.* 1962; WENCKERT 1963). In the present series a diameter of more than 10 mm was also the most common finding in the first films (Fig. 6). All tumours were more than 10 mm across when removed. FICHEL *et al.* (1963) could not trace a single report of a carcinoma that had been undetected by dem-



Fig 5 Man aged 49 examined because of constipation a) A rectal polyp 8 mm x 9 mm about characteristics of malignancy overlooked b) Eighty four months later tumour 7 mm x 19 mm Histology Moderately to poorly differentiated adenocarcinoma with invasion of the muscularis propria Eight years later perineal recurrence

Discussion

The diagnostic value of roentgenographic signs believed to indicate malignancy depends on how often also benign lesions have such features. This question is still open. A long term prospective observation of patients with a random selection of various polypoid lesions of the colon rectum, not subjected to excision until late, would probably be valuable in this respect, but since this cannot be performed in man the problem can be approached only by retrospective analyses.

The radiologic abnormalities described as signs of malignancy and which have been used in the present material are encountered more often in malignant



Fig 6 Woman aged 79 examined because of constipation a) A 10 mm x 14 mm polyp of the sigmoid colon without signs of malignancy overlooked b) Twenty two months later an nodular tumour 40 mm in diameter at the site of the previous polyp Histology Moderately differentiated nodular adenocarcinoma growing through the bowel wall all the lymph node metastases Recurrence 8 months later after another 3 months the patient died Autopsy Hepatic metastases

Growth rate. The most reliable sign of malignancy, however, seems to be an increase in size. On the basis of over 300 cases of polypoid tumours of the colon, KATZEL et coll. (1965) concluded that the measured growth rate can be utilized in deciding whether a polyp is benign or malignant. WELIN et coll. (1963) studied the growth rate in serial films of 375 tumours of different morphologic types and reported that polyps that grew fast were more often malignant than the others. Most benign and unremoved polyps did not increase in size. WELIN et coll. found carcinomas to have a linear diametric growth rate of 0.09 to 0.75 mm per month (median 0.24 mm). In the present series the corresponding figures were 0.06 to 0.90 mm per month (median 0.52 mm). The tumours varied somewhat in growth rate (Table 1) but no correlation seems to exist between the growth rate and the stage of the tumour at operation.

For correct assessment of growth rate as well as of roentgenographic features of malignancy it is imperative that the bowel be perfectly clean to permit detection and demonstration of the morphology of small lesions. It is probable that 6 of the present cases were overlooked because of an unsatisfactory clearing of the bowel.

Life history. The 153 tumours revealed that in spite of the long (average 5 years preoperative) observation period 30 per cent were in group A (Dukes 1953) when removed and the overall 5 year survival rate was as high as 57 per cent. These findings suggest that the natural history of at least some carcinomas of the colorectum is fairly long. Nevertheless, even small polypoid lesions with roentgenographic appearance of malignancy indicate surgery in order to forestall metastatic disease. In 14 of the present cases, not operated upon until a certain period after the appearance of such polyps, metastases were found at the operation or later.

Conclusion. Tumours with roentgenographic appearance of malignancy should be removed as soon as possible. In the absence of malignant sign, careful observation with repeated roentgenography is imperative.

SUMMARY

Thirty patients treated for carcinoma of the colon rectum which had already been shown in retrospect to grow from small polypoid tumours were analysed. Repeated double contrast roentgenography performed before the operation during a mean observation time of 5 years. When first demonstrated all but 4 of the polypoid tumours had at least one roentgenographic sign of malignancy. The mean linear diametric growth rate was 0.51 mm/month. The 5 year survival rate was 57 per cent. Metastases were found in 19 cases.

ZUSAMMENFASSUNG

Dreissig wegen eines Colon Rectum Carzinoms behandelte Patienten, welche wie retrospektiv gezeigt werden konnte, von kleinen polypoiden Tumoren aus gewachsen war, wurden analysiert. Wiederholte Doppelkontrast Röntgenuntersuchungen waren vor der Operation



Fig 8 Same case as in Fig 7. One year after biopsy the tumour measured 8 mm x 24 mm. b) After another year 20 mm x 69 mm. Abdomino-perineal amputation of the rectum. Histology: Moderately to poorly differentiated adenocarcinoma growing through the rectal wall; no metastases in the regional lymph nodes; no benign remnant. The patient survived the operation 108 months. Autopsy: No signs of recurrence.

observation of a local polypoid tumour less than 10 mm across by more than 2 years. The present series, however, included one such example (Fig 4). In this series almost one third of the polyps which were later removed as carcinomas were originally smaller than 10 mm in diameter. It is therefore important that also the other signs must be carefully looked for in small polyps.

Irregular surface. WELIN (1967) found that carcinomas have a rough cauliflower-like surface instead of a smooth surface statistically more often than benign lesions. In the present series the second most common roentgenographic sign of malignancy of the original polypoid lesion was an irregular outline. It occurred in more than half of the cases at the first examination and in all the other cases during the observation period (Figs 3, 7, 8).

Base. Sessile polyps are often regarded as being more apt to be malignant than are pedunculated polyps. WELIN (1967) found that sessile polyps with a broad base i.e. by definition polyps where the base of the polyp in the profile view exceeds the height of it, were more likely to be malignant than benign. Using the same criterion for a broad based polyp as WELIN (1967) it was found that 9 of the polyps in the present series were broad based. In films from the last roentgen examination all but 6 were broad based. This sign seems to be valuable though it is probably less often encountered if the polyp is very small.

Indentation of the bowel wall was seen at the first examination in only 6 of the present cases. This might be due to the fact that tangential projections which are necessary for its detection were available in only half of the cases. Indentation is an important sign in broad based polyps (WELIN 1967) and almost pathognomonic of infiltrative growth (WELIN 1971). But the absence of indentation does not exclude the possibility of malignant degeneration. It was observed in all but 5 cases at the last examination in the present series.

CONCEPTUAL FRAMEWORK OF A COMPUTER BASED LIBRARY CIRCULATION SYSTEM FOR THE RADIOLOGY FILE ROOM

JAMES WINTER and MARK ALLEN STEIN

The growing size and complexity of many medical centers results in difficulty in locating patient information. The breakdown of manual library circulation control has resulted in serious inefficiency in radiology film libraries in many hospitals. The inability to locate the film jacket for review or comparison with current examinations is a problem of increasing concern to the radiologist. Even temporary inability to locate films greatly impedes patient care and is extremely frustrating to all concerned. Errors occur because films are lost when decisions must be made. Unnecessary repetition of examinations occurs, with the attendant risk, discomfort and expense. A great deal of valuable physician time is wasted when retrieval is delayed. These problems are aggravated by the difficulties encountered in obtaining competent and motivated medical library personnel. Unfortunately, these problems are often not given the attention they deserve due to failure to appreciate the magnitude of the problem (Jostrop & Gross 1966) or the severity of the consequences.

Improved health care delivery would result from eliminating the film room circulation problem. However, a conceptual framework is needed before it

Submitted for publication 2 April 1973

während einer durchschnittlichen Zeit von 5 Jahren vorgenommen worden. Wenn um ersten mal nachgewiesen hatten alle außer 4 der polypoiden Tumoren zu mindest ein mit endoskopischen Zeichen von Malignität. Die durchschnittliche lineare Wachstums geschwindigkeit im Diameter betrug 0.61 mm/Monat die 5 jährige Überlebenssequenz betrug 57%. Metastasen wurden in 19 Fällen gefunden.

RÉSUMÉ

Les auteurs ont étudié 30 malades traités pour cancer du colon et du rectum qui s'étaient développés comme on peut le montrer rétrospectivement à partir de petites tumeurs polypoides. Des examens radiographiques répétés en double contraste ont été faits avant l'opération pendant un temps d'observation moyen de 5 ans. Quand elles ont été mises en évidence pour la première fois toutes les tumeurs polypoides sauf quatre avaient à moins un signe radiographique de malignité. Le taux moyen de croissance linéaire de leur diamètre était de 0.61 mm par mois. Le taux de survie à 5 ans était de 57%. Les auteurs ont trouvé des métastases dans 19 cas.

REFERENCES

- ANDERSON L, FAHREBERG S and WILLY S. Roentgen diagnosis of small polyps in the colon and rectum. *Acta radiol* 43 (1953) 201.
- BELLY T, EXELLER G, MALLIER C, PHIL B and WILCHARTY A. Carcinoma of the colon and rectum in a defined population. An epidemiological, clinical and postmortem investigation of colorectal carcinoma and coexisting benign polyps in Malmö, Sweden. *Acta chir scand* (1973) Suppl N. 438.
- DEER C E. The classification of cancer of the rectum. *J Path Bact* 35 (1932) 323.
- ESTERLINE H T, EVANS G W, MERCADO LLOO R, MILLER L and FITT W T J. Malignant potential of adenomas of colon and rectum. *J Amer med Ass* 179 (1962) 322.
- FRIEDL L S, FRIEDL S J and WERTHEIMER F K. Roentgenologic observations of growth rates of colonic polyps and carcinomas. *Acta radiol Diagnost* 3 (1963) 417.
- SPRATT J S JR and ACHERSON L V. Relationship of the size of colonic tumors to their histologic composition and biologic behavior. *Surg Forum* 10 (1960) 36.
- WILLY S. Results of the Malmö technique of colon examination. *J Amer med Ass* 199 (1967) 369.
- The radiological detection of early carcinoma. *J belge Radiol* 54 (1971) 21.
- YOUNGER J, SPRATT J S JR, LINELL F, GRYLL H J, JOHNSON R E and ALERMA L A. The rates and patterns of growth of 375 tumors of the large intestine and rectum observed serially by double contrast enem. study (Malmö technique). *Amer J Roentgenol* 90 (1963) 673.
- WILCHARTY A. Cancer of the colon and rectum. *Acta chir scand* (1963) Suppl N. 332 p 73.

Title Acid RadioVol. 15 Year 1976 (Dis)

Borrower's N	Due Date	Borrower No	Due Date
69	10 8 79		
193	16 11 79		
38	10 3 80		

number of jackets in circulation, film jacket, and the frequency of film jackets to leave the radiol problem and is unacceptably resting high quality rapidly produced economically viable alternative at

The circulation problem is also and the medical record library (and can be dealt with independent nature of the volumes they contain concepts or techniques to be presented. If this generality is recognized and shared among multiple users

Before the problem can be applied must be made explicit (WATSON comp) with stringent rules which time to carry films to a central location. Therefore restrictions on circulation jacket locations to be rapidly should be eliminated when possible.

A fixed loan period is desirable of the attributes of the film jacket renewals ensure that the borrower may be fined suspension of borrowing privileges, or other means, but should be effective in promoting prompt return or renewal and in discouraging loss. Removal of film jackets from the radiologic department without notifying the circulation system constitutes theft just as it would in the public library. Severe sanctions should be imposed to discourage this. Failure to identify and promptly retrieve overdue and stolen film jackets until the time of the next request is a major cause of loss of control.

The objective of a circulation system (locator) is to provide current knowledge of film jacket locations while allowing complete freedom to obtain and relocate them. This is achieved by requiring that the locator be notified of each and every relocation of a film jacket. This requirement is realistic if the notification procedure is simple and the locator is readily accessible. The notification procedure is the same regardless of the nature of the relocation. Transferring film jackets between doctors between doctors and file rooms and between file room film bins involves identical procedures.

Equivalence of relocation procedures is possible because both people and places may act as borrowers. Placing a film jacket in a file room bin is analogous to

as also needs the film jacket. Incentives

tempting a solution. This communication sets forth the underlying concepts for efficient radiology film library circulation control.

Manual circulation control

Circulation control is built upon a charging system which records pertinent information regarding loans. These systems generally include provisions for handling reserve requests and recalling overdue material.

Radiology film and medical record libraries differ from most public and private libraries: (a) activities occur at an accelerated pace; (b) circulating volumes must be immediately traceable; (c) shelving arrangement is usually based on accession number (the hospital number) rather than on subject classification; (d) a closed stack policy is usually adopted allowing only file room personnel to shelve and unshelve volumes; (e) loans occur between borrowers outside the library; and (f) volumes are created, destroyed, and combined upon demand.

A review of the charging systems used in public (FRY et coll 1961, GEER 1955, HOOE et coll 1961) and medical school libraries (BALLEVA 1966) shows that many of the systems commonly in use suffer from a number of shortcomings. The most efficient techniques employ photographic or other mechanical methods to record circulation information. These techniques are awkward in dealing with reserve requests and fail to provide a mechanism for readily locating a particular circulating volume because they record loans in the order that they occur. Only the tedious and less efficient manual methods deal satisfactorily with these problems (FRY et coll). These offer drawbacks in the form of increased labour and chance for error in manual transcription of information. A communication technique to allow easy and accurate borrowing of volumes from remote locations is not available with conventional circulation methods.

There has recently been considerable interest in library automation. Computer based circulation systems are being developed for public and university libraries (CHAPMAN et coll 1970, HAYES & BECKER 1970) as well as for medical school libraries (PAYNE et coll 1966, PIZER et coll 1964) in an attempt to overcome the limitations of manual systems. However, these endeavours have not been focused on the radiology film library.

Concepts for designing automated locator systems

The problem is the inability to locate roentgen film jackets. The most recent examinations are the most active, most frequently requested, and most difficult to find. The magnitude of the file room problem depends largely upon the

Table

The structure of information that a locator must retain. Interrelationships among the entries demonstrate the application of the concepts

Volume		Borrower		Date	Status
Type	Identification	Type	Identification	(Time)	
Film jacket	042 75 10 4	Clinic	Orthopedics	8/7	Due
Film jacket	047 21 93 2	Doctor	R. M. Williams	8/8	Due
Film jacket	047 21 9 3	Operation theatre	No 3	8/8	Due
Medical chart	04 21 9 3	Doctor	S. J. Jones	8/5	Due
Film jacket	047 1 95 3	Room	Big demon	8/8	Even
			stration No 2		
Film jacket	017 31 80 7	Film bin	Medical No 7	8/6	Due

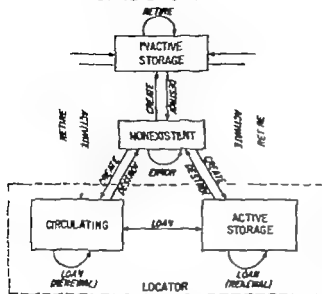
These labels may or may not be numerically related to the hospital number and are reassignable. Uniqueness and reassignability eliminate the multiple film jacket ambiguity and the need to maintain a record of all film jackets belonging to each patient respectively.

Film jackets may be regarded as being in one of four possible states determined by the borrower to which they are assigned: (a) circulation outside the library, (b) active storage in the library, (c) inactive storage in the library, and (d) non-existent. A circulation system must retain the current locations of circulating and active film jackets only. The types of relocations and their effects on the states of the film jackets are summarized in the figure.

The borrower possessing the largest number of film jackets is the inactive storage area. It is the only borrower that need not be identified by a circulation system. Therefore any film jacket with an unspecified location is either in inactive storage or non-existent. This greatly reduces the amount of information a locator must retain and is feasible because relocation of inactive film jackets is infrequent. An inventory of film jacket locations in all states may be provided as a by-product. The inventory includes the locations of inactive film jackets even if multiple inactive storage areas exist. This resolves the ambiguity between inactive and non-existent film jackets as well as providing the actual number of film jackets existing and destroyed for each patient.

Due dates are computed upon relocations and must be retained for all active and circulating film jackets. Renewals are simply relocations to the same borrower resulting in a new date. Because of the borrower equivalence concept, film jackets in film room bins also have due dates: the need to return the jackets because of inactivity is apparent when they become overdue.

STATE DIAGRAM



An identical procedure may be used to notify the circulation system of all of these locations. However, only locations of film jackets in circulation and active storage need be retained by locator. Assignment of film jackets to inactive storage or to the non-existent state may be noted but need not be retained.

lending it to an individual. The need to find film jackets within the radiologic department and its file and film demonstration rooms as well as when lent to individuals underlies the equivalence of borrowers.

Borrowers may be identified by specifying the borrower type e.g. physician and the borrower identification e.g. John Smith. It should be the responsibility of the borrower, not the lender, to notify the circulation system of a loan because the borrower is better able to identify himself and assume responsibility.

Each film packet may be uniquely identified by specifying the volume type e.g. film packet and the volume identification. The latter is related to the hospital number of a patient. In the simplest case, the volume identification is the hospital number. However, when multiple film jackets exist for a given patient, use of the hospital number alone fails to identify which film jacket is being referenced.

This ambiguity can be avoided if each film jacket is assigned a number unique among that patient's film jackets. The hospital number plus the assigned number then uniquely identify any film jacket. This method is only feasible if all previously assigned numbers for a given hospital number are known at the time the next number must be assigned (next film jacket is created) for that patient.

Since this is frequently not the case in radiology, a better technique for avoiding this ambiguity is to maintain a set of unique labels to be used as volume identifiers and to assign one of these to each film jacket that will be referenced.

RÉSUMÉ

L'impossibilité de retrouver les pochettes de films radiologiques est coûteuse et préjudiciable aux soins des malades dans de nombreux hôpitaux. L'inadaptation des techniques manuelles pour régler leur circulation motive la mise au point de concepts nécessaires pour la création d'un système automatique de recherche. Les auteurs ont construit un modèle de remise en place des pochettes de films. Les auteurs ont dégagé les concepts qui sont à la base de l'identification des pochettes de films et des emprunteurs et à la base d'un choix des règles des techniques de circulation dans les bibliothèques.

REFERENCES

- BALFORD J. B. Topics in library technology: changing systems. *Bull. med. Libr. Ass.* 54 (1966) 33.
- CHAPMAN E. A., ST. PIERRE P. L. and LEBANS J. Library systems analysis guidelines. Chapter 11. Total systems: concepts in the design of a computer based circulation system. John Wiley & Sons, Bristol, 1970.
- FRY C. et al. Study of circulation control systems. Library technology project of the American Library Association and the Council on Library Resources, Inc. Chicago, 1961.
- GREY H. T. Changing systems. *Amer. Libr. Ass.* Chicago, 1955.
- HAYES R. M. and BRUCKER J. Handbook of data processing for libraries. Chapter 15. Circulation control sub-system. John Wiley & Sons, Bristol, 1970.
- HOGG F. A., MATTHEWS W. J. and VARRY T. E. A report on a survey made of book-charging systems in present use in England. *The Libr. Ass.* London, 1961.
- HUTCHMAN F. K. Manual for medical record librarians. Chapter 7. Numbering and filing medical records. Physicians Record Co., 1960.
- JYDESTEIN R. A. and GROSS M. J. Cost of information handling in hospitals. *Health Serv. Pers.* 1966 233.
- PALMER I. M., SMALL L. and DRYETT E. T. Mechanization in a new medical school library. II. Serials and circulation. *Bull. med. Libr. Ass.* 54 (1966) 337.
- PERKINS I. H., ANDERSON I. T. and BRADMAN E. Mechanization of library procedures in the medium sized medical library. II. Circulation records. *Bull. med. Libr. Ass.* 52 (1964) 370.
- WATKINS C. and COOPER N. C. Circulation policies in health science libraries. *Bull. med. Libr. Ass.* 58 (1970) 548.

Reserve requests indicate a desired rather than an accomplished relocation. Therefore the reserve is like a relocation except that the desired rather than the due date is specified.

The information maintained in a circulation system (Table) must be available upon request. Overdue and reserve lists must be supplied at appropriate times. These should be listed according to borrower and shelving arrangement respectively to optimize the efficiency of file room personnel.

Conclusions

Current manual techniques of circulation control fail to adequately locate film jackets especially in the teaching hospital setting. This results in poor health care delivery and is expensive, time consuming and frustrating. Concepts underlying a general solution to the circulation control problem are presented as a foundation for anyone designing a computer based locator system: (a) a minimum set of library rules sufficient to provide knowledge of film jacket locations, (b) use of identical procedures for communicating film jacket relocations to a locator system based upon identical treatment of all borrowers, (c) a technique for overcoming the problem of ambiguity in identifying multiple film jackets belonging to the same patient, (d) minimizing the information retained by a locator system without compromising knowledge of film jacket locations, (e) methods for handling reserve requests, for detecting and recovering overdue and lost film jackets, for purging inactive film jackets and for maintaining inventory.

SUMMARY

The inability to locate roentgen film jackets is expensive and degrades patient care in many hospitals. Inadequacy of manual techniques for controlling circulation motivates the development of concepts needed for designing automated locator systems. A model of film jacket locations is constructed. Concepts underlying the identification of film jackets and borrowers and the selection of library circulation rules and procedures are indicated.

ZUSAMMENFASSUNG

Die Unmöglichkeit Röntgenfilm Umschläge zu lokalisieren ist teuer und setzt die Patientenversorgung in vielen Krankenhäusern herab. Die Unmöglichkeit einer manuellen Technik um die Zirkulation zu kontrollieren motiviert die Entwicklung von Begriffen die gebraucht werden um ein automatisches Lokalisationssystem zu entwerfen. Ein Modell zur Relokalisation von Filmumschlägen ist konstruiert. Die zugrundeliegenden Begriffe zur Identifikation der Filmumschläge und Entleiher und die Auswahl von Bibliotheks Zirkulations Regeln und die Handlungsmuster werden dargestellt.

Publishers Warsaw 1972

LEITCH-ATIN L. Bone tumors 4th edition C V Mosby Company St Louis 1972

LEVENHEIM R. Uncoupling the radiology system Hospital Research and Educational Trust Chicago 1971

MERLIAN I. Analysis of roentgen signs Vol 1 Introduction Skeletal systems Vol 2 Respiratory system heart Vol 3 Abdomen Urogenital and alimentary tracts W B Saunders Company London 1973

MONOGRAPHIES DES ANNALES DE RADIOLOGIE Matériel et techniques en radiologie pédiatrique Textes réunis par P Joire et J F Huquet Expansion Scientifique Française Paris 1973

NEVTON W T and DONATI R M. Radioassay in clinical medicine Charles C Thomas Springfield 1974

PAK TRICHIT FORTEILBA. GEBILDE FÜR DIE PRAXIS Solide maligne Tumoren im Kindesalter Vol 9 Herausgeber E Röss S Karger Basel 1974

THE PHYSICS OF RADIOLOGY NO. 1 Report A An introduction to diagnostic radiological systems HPA Report No 6 Report B Measurements referring to diagnostic x ray beams HPA Report No 7 Report C The assessment of x ray image intensifier and television system performance HPA Report No 8 The Hospital Physicians Association London 1973

JAZON J. La colonne lombo sacrée Doin éditeurs Paris 1972

POM L N W. Handbook for radiologic technologists and special procedures nurses in radiology Charles C Thomas Springfield 1974

POZYNA SKI A K. The hand in radiologic diagnosis (SMCR-4) W B Saunders Company London 1974

RADIOLOGICAL ATLAS OF BONE TUMOURS Vol 2 By the Netherlands Committee on Bone Tumours Mouton & Co Hague 1973

REUTER S R and RYMA H C. Gastrointestinal angiography W B Saunders Company London 1972

ROBERTSON B. Microangiography of the lung in infancy and childhood Iropps b'cker Stockholm 1973

SANTON H M and STRICKLAND B. Practical procedures in diagnostic radiology 2nd edition H K Lewis & Co London 1972

SCHULZBERG M H. Indications and alternations in x ray diagnosis 2nd edition Charles C Thomas Springfield 1974

STEIN G N and FERGUSON A K. The duodenum small intestine and colon An atlas of tumor radiology Lloyd Luke London 1973

- The esophagus and stomach An atlas of tumor radiology Lloyd Luke London 1973

TERRY W C and McLAREN J W. Planning a diagnostic radiology department W B Saunders Company London 1973

THE TEXT BOOK OF X-RAY DIAGNOSIS 4th edition Vol II Cardiovascular system Edited by S Cochrane Shanks and Peter Kerley H K Lewis & Co London 1972

SPORN ROSEALD H. Diagnostic radiology in clinical medicine Lloyd Luke London 1973

VLAMOVITCH H et FLEURY J M. Les repères neulaires dans la pratique de l'angiographie aréologique Les monographies des annales de radiologie 7 Édition Scientifique Française Paris 1973

WESTBEEK R I. The newborn chest Harper & Row Hagerstown 1973

WILLIAMS A. Les images mammographiques S Karger Basel 1972

WITTM A I. Endoskopische Biopsie Ein Rundschreiben Akademie Had6 Budapest 1972

(THE) YEAR BOOK OF RADIOLOGY 1973 Radiologic Diagnosis Edited by Walter M Whitehouse M D Radiation Therapy Edited by Howard B Latourette M D Year Book Medical Publishers Chicago 1973

Books received

We acknowledge with thanks under this heading books received for review. We trust this will be regarded as a sufficient mark of appreciation of the courtesy of the sender. Reviews of selected items will appear as soon as opportunity affords.

- ADVANCES IN OTO RHINO LARYNGOLOGY Vol 21 Edited by S Brunner S Karger AG Basel 1974
- ANSELL G Notes on radiological emergencies and ed tion Blackw Il Scientific Publications Oxford 1973
- BAILEY J A Disproportionate short stature-diagnosis and management W B Saunders Company Ltd London 1973
- BALANCE H A ANPLATE K and LEVIN D C Coronary angiography Charles C Thomas Springfield 1973
- BURKETT E and MORLEY P Abdominal ecography Ultrasound in the diagnosis of abdominal conditions The Butterworth Group London 1974
- BURRITT A BRUNYER S and VAL AMORI G F Modern thin section tomography Charles C Thomas Springfield 1973
- CUFFY J Pediatric X ray diagnosis 6th edition Vols 1 and 2 Year Book Medical Publishers Chicago 197
- COLSTON PAPERS No 24 Bone Certain aspects of neoplasms Edited by C H G Price and F G M Ross The Butterworth Group London 1973
- COUSQUENT A Repères et mesures en radiodiagnostic Expansion Scientifique Française Paris 1974
- DIAGNOSIS AND TREATMENT OF PITUITARY TUMORS ICS N 303 Edited by P O Kohler and G T Ross Excerpta Medica Amsterdam 1973
- DIAGNOSTIC X RAY PROTECTION The role of the radiological protection Adviser H H A Report N 9 The Hospital Physicists Association London 1973
- EATON J B S and FERRUCIO J T Radiology of the pancreas and duodenum (S M C R Vol III W B Saunders Company London 1973
- ECOUTIER J Artériographie rénale Expansion Scientifique Française Paris 1972
- ELEMENTS DE SEVELOLOGIE RADIOLOGIE Cercle d'études et de recherches radiologiques Tome II Delachaux & Niestlé Paris 1977
- FELTON B Chest roentgenology W B Saunders Company Ltd London 1973
- FORRESTER D M and NEWSON J W The radiology of joint disease W B Saunders Company London 1973
- FRIEDMAN DAN J Roentgen examinations in acute abdominal diseases Third edition Charles C Thomas Springfield 1974
- ITO M YAMADA H KITAHARA K and SASAKI Y Nuclear hepatology Clinical and physiological aspects of liver disease by radionuclides Georg Thieme Verlag Stuttgart 1974
- JACOB C A and PARIS D Q Textbook of radiologic technology 5th edition C V Mosby Company St Louis 1972
- and PIERCE D T Laboratory manual and workbook in radiologic technology C V Mosby Company St Louis 1972
- JOYCEMAN K and REES S Clinical cardiac radiology The Butterworth Group London 1973
- KAUTMANN H J Progress in pediatric radiology Intrinsic diseases of bones N 4 S Karger AG Basel 1973
- KEATS T F An atlas of normal roentgen variants that may simulate disease Lloyd Lusk London 1974
- LAMARQUE J E Artériographie hépatique Masson & Cie Paris 1974
- LES CYCLES St Z Purulent and fibrous mediastinitis radiological diagnosis Polish Medical

